JOURNAL
OF THE
WASHINGTON ACADEMY OF SCIENCES

VOLUME 41 October 1951 No. 10

ASTRONOMY.—*The birth of stars from interstellar clouds.*[1]

LYMAN SPITZER, JR., Princeton University Observatory. (Communicated by Richard K. Cook.)

The diversity of the stars is seemingly infinite. Even a superficial study shows enormous differences in stellar sizes, brightnesses, and surface temperatures. More detailed examination reveals also differences in speeds of motion and of rotation, in constancy of brightness and shape, in the intensity of magnetization, and in chemical composition. If all this complex yet partially ordered heterogeneity resulted from differences in the process of star formation, the task of the cosmogonist would be indeed staggering.

Fortunately the problem is much simplified by an important discovery made by W. Baade. Broadly speaking, all stars can be divided into two types, named by Baade population types I and II, respectively. According to the hypothesis we shall consider here these two types of stars have had radically different origins, with those of type I formed relatively recently from interstellar clouds, and type II formed at the beginning of the universe, some 3 billion years ago. Stars of population type I we shall call "cloud stars"; these stars may be forming continuously, and we can hope to investigate in some detail the manner of their birth. Stars of population type II we shall call "primeval stars"; conditions may well have changed so much since these stars were created that a reliable and detailed theory of their formation may not yet be possible.

OBSERVED DIFFERENCES BETWEEN TWO TYPES OF STARS

Velocities.—The evidence for these two distinct types of stars may be reviewed briefly. As pointed out in the pioneer work by Oort, stellar velocities provided the first indication for this separation of stars into two categories. As soon as radial velocities could be determined with the spectrograph it became evident that the velocities of stars in the line of sight were distributed over a wide range. Quite unexpectedly, the physical properties of stars turned out to be correlated with their radial velocities. For example, the random radial velocities of Cepheid variable stars, whose light varies regularly with a period of some 2 to 50 days, have a root mean square radial velocity of some 10 km/sec in the galactic plane. These stars are of population type I. On the other hand, the RR Lyrae variable stars, whose period of light variation is only a day or less, but which are otherwise rather similar to Cepheid variables, show radial velocities with a root mean square value of 120 km/sec in the galactic plane. These are type II stars. This large difference in radial velocity was readily detected, especially since no elaborate techniques were required to identify a variable star in either of these two categories; simple photometric observations can determine if a star is variable and, if so, fix the nature and period of the variability.

More recent work has shown similar differences between various types of stars, and the primeval type II stars are now thought to be high-velocity stars generally, while the cloud stars of type I are moving more slowly. For example, there are many stars which are considerably less luminous than the average for their surface temperature, and which must be considerably smaller than the average dwarf star. These are called "subdwarfs." Their radial velocity relative to

[1] The twentieth Joseph Henry Lecture of the Philosophical Society of Washington, delivered at the 1344th meeting of the Society on March 23, 1951, and presented under the title "The Formation of Stars."

the other stars has a root mean square value of about 150 km/sec in the galactic plane, and these may also be regarded as primeval stars. On the other hand, most stars in the neighborhood of the sun, like the sun itself, have random motions of some 10 to 20 km/sec, and these are stars of population type I, or cloud stars.

Luminosity.—A second major difference between the high-velocity primeval stars and the low-velocity cloud stars is the distribution of luminosity among stars of these two types. The lack of low-velocity subdwarfs has already been noted. More striking yet the brightest stars have low velocities, with no high-velocity stars more luminous than about 2,000 suns. By contrast, the supergiant low-velocity star Betelgeuse sends out as much light and heat as about 25,000 suns, while the luminosity of certain O-type supergiants must exceed 100,000 suns. The absence of primeval supergiant stars is a striking fact.

This particular difference between cloud stars and primeval stars is presented in more detail in Fig. 1, which shows somewhat simplified Russell-Hertzsprung diagrams for these two stellar types. The bolometric luminosity, in units of the solar luminosity, is plotted on a logarithmic scale against the spectral type, which measures the surface temperature. The bolometric luminosity of a star is simply the total amount of energy which it radiates per second. The diagona

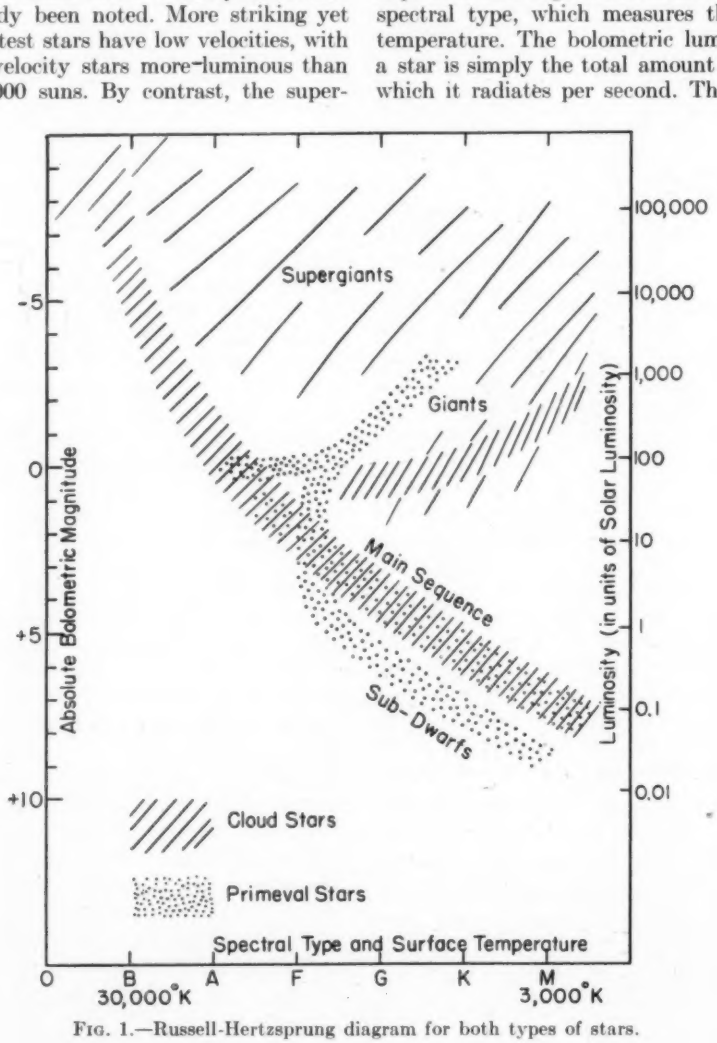


FIG. 1.—Russell-Hertzsprung diagram for both types of stars.

TABLE 1.—LIFETIME OF STARS OF DIFFERENT MASS

Mass M (in solar masses)	0.4	0.6	0.8	1.0	1.5
Mean Luminosity $\bar{L}$ (in solar luminosities)	.044	.034	1.4	4.4	34
Lifetime (in years)	7×10^{11}	1.4×10^{11}	4.4×10^{10}	1.8×10^{10}	3.5×10^{9}
Mass M	**2**	**4**	**6**	**8**	**10**
Mean Luminosity $\bar{L}$	140	4,400	34,000	150,000	440,000
Lifetime	1.1×10^{9}	7×10^{7}	1.4×10^{7}	4.4×10^{6}	1.8×10^{6}

hatching indicates areas of the diagram where the cloud stars appear, while primeval stars are found primarily in the dotted regions.

Many of the differences between the Russell-Hertzsprung diagrams for these two stellar types are not yet explained. However, the lack of supergiant primeval stars has a very simple physical explanation. According to our present theory of internal constitution, a star liberates energy by the combination of four hydrogen nuclei to form helium. When all the hydrogen is gone, the star cannot go on; it may collapse to form a white dwarf or possibly explode to form a supernova. A very luminous star burns its nuclear fuel so rapidly that it cannot shine very long, and the very brightest stars cannot have been shining at their present rate for anything like three billion years.

To compute the age of these very luminous stars we may start with the mass-luminosity relation derived from the theory of stellar interiors,

$$L = AM^5\mu^7T_c^{1/2} \qquad (1)$$

where L, M, and T_c are the luminosity, mass, and central temperature of the star and μ is the mean molecular weight. The quanity A depends on a number of physical constants and on the distribution of density within the star. This equation is valid only for stars built according to the same model as the sun; i.e., with the same relative variation of density with depth. However, it may give at least the order of magnitude for other stars. In applying this formula we shall assume that the central temperature, T_c, is the same in all stars.

To discuss the age of a star we must take into account the change of μ with time, resulting from the conversion of hydrogen into helium. The rate of this conversion, which liberates the energy radiated by the star, is readily determined from the observed luminosity, yielding the equation

$$\frac{d\mu}{dt} = \frac{5\mu^2 L}{4\zeta c^2 M}, \qquad (2)$$

where ζ is the fraction of mass liberated when four hydrogen atoms combine to produce a helium atom, and c is the velocity of light. The star, when formed, will be composed mostly of hydrogen, with some helium, and with μ equal to about 0.6. When all the hydrogen is gone, μ increases to 4/3.

From equations (1) and (2) the change of μ and L with time may be computed. Table 1 gives the age required for exhaustion of the hydrogen for stars of different mass, together with the average luminosity $\bar{L}$ during this period. In the computation of this table the constant A in equation (1) has been chosen to give the observed luminosity for the sun, with μ equal to its assumed initial value, 0.6. Toward the end of a star's life, the luminosity rises far above the average, and Table 2 gives the fraction of time that a star's luminosity exceeds the average luminosity by various factors. It should be noted that the values given for large p in Table 2 are probably too great, especially for the more massive stars. Stars that have exhausted most of their hydrogen may be composite, with a helium core, a surrounding envelope of hydrogen, and a different luminosity from that obtained from equation (1). In addition, radiation pressure, which was neglected in the derivation of equation (1), will become important when $M\mu^2$ exceeds about 10; scattering of radiation by free electrons will also be important in this range, and both these effects will tend to decrease the luminosity. For these reasons, the masses given in Table 1 for

stars of short life and high $\bar{L}$ are somewhat too small, although the values of the lifetime for different values of the ratio $\bar{L}/M$ do not depend on equation (1) and should be accurate.

From these results let us compute the greatest possible age for a star 2,000 times as luminous as the sun, about the maximum observed for the primeval stars. If the star is just exhausting its last hydrogen, its luminosity will exceed its mean value for that star by a factor of 60.9. If the mass of the star is 1.5 times the solar mass, its mean luminosity will be about 34 suns, giving the required terminal luminosity of 2,000 suns and an age of 3×10^9 years. Actually these particular stars are giants, with probably an inner region mostly of helium surrounded by an atmosphere of hydrogen, and more detailed computations for such configurations would doubtless change the age somewhat. However the general agreement between the age of the high-velocity type II stars and the probable age of the universe certainly suggests strongly that these stars are, in fact, primeval. By contrast, the age of a supergiant star with a spectral type O whose luminosity exceeds 100,000 suns, is less than about 2×10^8 years even if these stars are mostly composed of helium. Such stars are unquestionably young.

Location.—A third major difference between cloud stars and primeval stars is in location. Primeval stars are found in almost all types of stellar systems—in globular clusters, in spherical, elliptical and spiral galaxies. Cloud stars are found only where interstellar clouds of gas and dust are present, which means primarily in the arms of spiral galaxies. In particular, the supergiant cloud stars are a characteristic feature of spiral arms, but are completely absent from other stellar systems, where gas and dust are lacking and where only primeval stars are found.

Composition.—A final difference between primeval stars and cloud stars is in chemical composition. These differences are not striking but seem definitely real. The atmospheres of high-velocity giants, of types G and K, show considerably weaker bands of the molecule CN than do the corresponding low-velocity giants. The CH bands, on the other hand, are strengthened; a recent analysis

TABLE 2.—INCREASE OF STELLAR LUMINOSITY WITH TIME

p	.25	.3	.4	.6	.8	1	1.5
Fraction of star's life in which L exceeds pL	.87	.70	.52	.33	.24	.18	.11
p	2	4	6	8	10	20	40
Fraction of star's life in which L exceeds pL	.081	.026	.021	.015	.012	.0043	.0011

The total range of p is from 0.228, when μ equals 0.6, to 60.9, when μ equals 1.33.

indicates that CH molecules are more abundant by a factor of about 2 in the "reversing layer" of a primeval star than in the cloud stars, while the iron atoms are less abundant by about the same ratio. These effects seem rather complicated at first sight, but it now appears that these differences may all follow from a greater preponderance of the somewhat heavier elements in the cloud stars as compared to the primeval stars.

It has been known for some years that most stars are almost entirely composed of hydrogen and helium. In fact, a chemist would regard stellar material as a mixture of "chemically pure" hydrogen and helium, since all the other elements together are present to less than one part in a thousand, by volume. The difference in composition between cloud stars and primeval stars seems to be that the former have perhaps twice as many of these impurities present as do the latter. Moreover, in the cloud stars, the ratio of iron to the carbon-nitrogen-oxygen group may be somewhat greater—perhaps by a factor of two again—than the corresponding ratio in the primeval stars.

The greater abundance of those heavier atoms in the cloud stars has two effects. Firstly, it increases the opacity in the stellar atmosphere, since it is the electrons from the easily ionized metals that do the absorbing and emitting in the atmosphere of a star whose spectral type is G, K, or M. Secondly, it increases the number of absorbing molecules per gram of matter, the increase in CN being twice as great (on a logarithmic scale) as the increase in CH. These two effects tend to offset each other, with the increase in the number of molecules winning out in the case of CN, but the increase in the continuous opacity, with a consequent decrease in the amount of matter above the

visible stellar surface, winning out in the case of CH.

It should be emphasized that these results refer to stellar atmospheres, rather than to stellar interiors. In a primeval giant star the hydrogen is mostly gone from the interior but the star is not well mixed and the atmospheric layers still retain their original composition. In fact it may be just this difference in composition between the inner and outer layers of a giant star that accounts for the large radius of such a star.

The differences outlined above between these two types of stars are summarized in Table 3. While some of the most important differences between primeval stars and cloud stars can apparently be explained, at least in a preliminary way, there are others which are less well understood. Why do planetary nebulae occur only around primeval stars? Why are the periods of variable stars so different in these two types of stars? Why do the rotational velocities of the cloud stars depend so sharply on spectral type, with low rotational speeds for stars cooler than type F5? When we know how a planetary nebula is formed, why stars pulsate, or how their rotation changes with time, perhaps we can then hope to understand these and other characteristics of cloud and primeval stars.

BIRTH OF PRIMEVAL STARS

Now that these two broad types of stars have been uncovered, what can we say about the origin of stars in each type? Concerning the formation of primeval stars we have relatively little information.

The problem is complicated by the fact that the density of matter in the universe may have been much greater several billion years ago than it is now. If we believe the observed velocity of recession of distant galaxies, all the galaxies were close together a few billion years ago, and what the physical conditions of matter were at that time is rather conjectural.

The chief clue is that the random velocities of these stars have now high average values. Since no mechanism has ever been suggested by which stellar velocities could increase up to a hundred kilometers per second during a few billion years, we must assume that these stars were formed with essentially their present velocities. One may envisage a turbulent gas, more distended than our present galaxy, and perhaps at a considerably higher temperature than the 60° K characteristic of the typical interstellar gas cloud at present. Condensations in this gas might then produce high-velocity stars of various types.

As time progressed, the brightest of these stars would exhaust their hydrogen and disappear. After a life of several billion years only the less luminous stars would be still shining. If we look ahead through time, we may foresee that in the next ten billion years more and more of these primeval stars will run out of atomic fuel and disappear. Galaxies without gas and dust will grow dimmer and dimmer, and gradually go out entirely. Except for any cloud stars still being formed in spiral galaxies, the Universe will gradually grow dark.

BIRTH OF PROTOSTARS FROM CLOUDS

We have seen that young stars are present in and only in those regions of space where interstellar matter is also found. The circumstantial evidence for the generation of these stars from clouds seems very strong, and the formation of all low-velocity type I stars from interstellar clouds is a natural working hypothesis, which explains immediately the difference in location between high-velocity and low-velocity stars.

TABLE 3.—DIFFERENCES BETWEEN CLOUD STARS AND PRIMEVAL STARS

	Type I Cloud stars	Type II Primeval stars
Velocities	Low, 10-30 km/sec (velocities of clouds)	High, 60-180 km/sec (turbulence in primeval nebula?)
Luminosities	Range up to 10^6 suns (young stars)	Brightest are 10^9 suns (old stars, formed 3×10^9 years ago)
Location	In spiral arms of galaxies with gas and dust (forming continually)	In almost all systems, including globular clusters and elliptical galaxies with no gas or dust. (Stars have no relation to present interstellar matter.)
Composition of atmosphere	10,000 H 1000 He 20 C—N—O 4 metals (concentration of grains relative to gas)	10,000 H 1000 He 10 C—N—O 1 metals (original composition of primeval matter)

Can we strengthen the net of evidence by showing in detail how a star can be formed out of "star dust"? Can we show that this theory explains the velocities and composition of these cloud stars? A detailed and rigorous demonstration of these points would be very difficult, and our present knowledge is insufficient for the task. However, the theory described here seems consistent with present evidence, and offers qualitative explanations of the various observational features already described.

Let us consider how a prestellar globule, or "protostar" might form from a gaseous medium between the existing stars. The criteria for condensation of a gas under gravitational forces were discussed by Jeans several decades ago. Jeans showed that a slight condensation would continue to contract under its own gravitational self-attraction if the initial size of the condensation exceeded a critical value l, given by the equation

$$l^2 = \frac{\pi k T}{G \rho m_0 \mu}, \qquad (3)$$

where T is the gas temperature in degrees Kelvin, k the Boltzmann gas constant, G the gravitational constant, ρ the material density, m_0 the mass of unit atomic weight, and μ the mean molecular weight. This equation is derived on the assumption that the contraction is isothermal. If the diameter of a cloud is less than l, the cloud cannot hold itself together by gravitational forces.

With equation (3) in mind, we may survey briefly existing information on interstellar matter, to see whether regions exist in which gravitational contraction is possible. From measurements of the Balmer lines of hydrogen near hot stars, we know that a hydrogen gas pervades interstellar space, with a mean density of about one atom per cubic centimeter. Helium is probably also present but cannot be observed. As in the stars, the other elements are present only as slight impurities. If this deduced mean density is substituted into equation (3), the temperature is set equal to 10,000° K, and μ is set equal to 0.5, corresponding to the nearly complete ionization of hydrogen in those regions where the Balmer lines are observed, l is found to be 2,300 parsecs (a parsec, the standard measuring rod in astronomy, is 3.26 times the distance travelled by light in one year). This distance is some ten times greater than the thickness of the galaxy, and no initial condensation of this sort can possibly occur.

This calculation should not be taken too seriously, since it is known that the distribution of interstellar matter is far from uniform. We can not observe interstellar hydrogen in detail in most regions, but we can observe certain of the impurities in the gas. Neutral sodium and ionized calcium atoms have strong absorption lines in the accessible part of the spectrum, and absorb light from distant stars: if these stars are of early spectral type (high surface temperature), the star's own atmosphere does not produce these particular lines. Observations of these interstellar absorption lines show that the interstellar matter is distributed in separate clouds, and that these clouds have appreciable random velocities, with a root mean square value of about 10km/sec in one coordinate. In addition, many of the atoms other than hydrogen and helium stick together to form molecules of greater and greater size, which finally become tiny solid particles, or grains, about 3×10^{-5} cm in radius. These grains, composed mostly of the hydrogen compounds ice (H_2O), ammonia (NH_3) and methane (CH_4), absorb and scatter starlight, the effect being much more pronounced for light of shorter wave lengths. Although their temperature is only 10° to 20° above absolute zero, the grains cannot retrain much hydrogen, since this element will rapidly evaporate or sublime at such temperatures. Study of the absorption and scattering by these clouds confirms the irregular distribution of interstellar matter, and gives important information on the sizes of the clouds. These range from small dense nebulae less than a parsec in size to enormous clouds, or rather cloud complexes, stretching over about a hundred parsecs.

The density in these clouds is rather uncertain, as is also the "kinetic temperature" which characterizes the random motions of the atoms in the gas. Theoretical computations indicate that the random motions of the neutral hydrogen atoms in a relatively dense cloud correspond to a gas at a tempera-

ture of about 60° K, somewhat above the temperature of the grains, but considerably less than the 10,000° obtained for the predominantly ionized hydrogen near a hot star. The chief reason for this drop in temperature is that the hydrogen is completely neutral in these clouds and there is no supply of kinetic energy resulting from the absorption of ultraviolet light by hydrogen atoms and the ensuing expulsion of photoelectrons. The density in one of these clouds is probably in the neighborhood of 20 times the mean density in interstellar space, or about twenty hydrogen atoms per cm^3. Outside the clouds the densities are probably less by a factor of about 100, and the temperatures may be greater by the same factor. Thus it appears that the gas pressure may be the same in and out of clouds, and, indeed, the drop of temperature in certain regions may be the primary reason for the formation of clouds, the gas contracting as its temperature falls.

If we take these values for a typical cloud, (3×10^{-22} grams cm^{-3} for ρ and 60° K for T), and insert them into equation (1), we find that l is 28 parsecs. This value is greater than the diameter of the typical small cloud. The vast cloud complexes are larger than 28 parsecs across, but in these the density is less, and the rotation of the galaxy will hinder the formation of a condensation. In fact, it is readily shown that in a system rotating with the angular velocity ω a condensation cannot contract gravitationally, regardless of its temperature, if the density is less than the limiting value $\omega^2/2\pi G$. In the galaxy, ω is about 10^{-15}, and the limiting density is about 2.5×10^{-24} gm/cm^3, or about one and a half hydrogen atoms per cm^3.

There is another condition that a cloud must fulfill if it wishes to condense. It now appears that a magnetic field is present in interstellar space. The plane polarization of light from distant stars can be explained only if a field B of about 10^{-5} gauss is present to orient the grains so that their long axes are oriented in one direction or in one particular plane. With this field the magnetic energy density $B^2/8\pi$ is about equal to the material energy density. Since the conductivity of the interstellar gas is relatively high, the magnetic lines of force are "frozen in" to the material. Any contraction of a cloud will bring the lines of force together and increase the magnetic field strength and this requires additional energy. Thus the gravitational force must be strong enough to overcome not only the gas pressure but also the magnetic field, both of which resist contraction. It may be shown that this effect will not modify equation (3) provided that the magnetic "pressure" $B^2/8\pi$ is small compared to the gas pressure $n_H kT$, where n_H is the number of hydrogen atoms per cubic centimeter in the gas. This criterion will be satisfied in a typical cloud if B is less than 2×10^{-6} gauss, considerably less than its average value.

Evidently a typical cloud cannot condense into stars. This is fortunate for the theory, since we know that clouds are still present, uncondensed, some three billion years since the universe was formed. Somewhat unusual conditions of low temperature, high density, and low magnetic field, such as only an occasional cloud might experience, are necessary to permit condensation to proceed. This review of the evidence gives us no reason to doubt the conclusion suggested by the observations; i.e., that new stars form continuously from interstellar clouds.

CONCENTRATION OF GRAINS

We have seen that the development of clouds suitable for star formation is theoretically reasonable and in accord with observations. Next we may inquire whether the composition of the cloud stars may reasonably be expected to differ from that in the primeval stars. We start with the plausible assumption that interstellar matter has the same composition as the primeval stars, an assumption which cannot as yet be checked with any precision. Then we have available an important mechanism for altering the distribution of heavy elements relative to H. This mechanism is the alteration of the ratio grains-to-hydrogen through the action of radiation pressure, a process which we shall now consider.

The existence of a pressure on any object absorbing or scattering light waves has been known for some time. This force is usually quite negligible in the laboratory, but in the space between the stars the effect becomes important, especially on tiny particles that

absorb vastly more light per gram than large objects do. The interstellar grains have a diameter about equal to the wave length of light, and for this size radiation pressure has the greatest effect. On the average the light in a galaxy is traveling in all directions. While a single grain will be knocked this way and that by the many photons it absorbs, it will not be pushed in any one direction.

This picture changes when many grains are considered. Now each little grain produces a shadow, and in this shadow there is no radiation to produce a force. If only two grains are considered, they will be pushed together by the radiation field, since in the shadow between them there is no light to push them apart. As the grains approach closer and closer, the shadow between them becomes blacker and blacker, and the force pushing them together goes up. As a result, radiation pressure produces a net attractive force between two interstellar grains which varies as the inverse square of the distance between them, exactly as the gravitational force, but which is several hundred times the gravitational force acting between the two grains. Calculations by Whipple show that if a cloud already contains a large number of grains, the radiation pressure attracting other grains outside the cloud will drive these grains through the gas and into the cloud, doubling the number of grains in the cloud within an interval of some 10^7 years.

An important result is apparent immediately. The grains are composed of compounds of the heavier elements with hydrogen; within a grain the ratio of hydrogen to other elements is only about 3 to 1, as compared with 1,000 to 1 in the gas. An increase in the ratio of grains to gas therefore results in a decreased ratio of hydrogen and helium to heavier elements within a cloud.

Moreover, the effect is likely to be even greater for metal atoms such as iron than for the carbon-nitrogen-oxygen group. According to the theory of Oort and van de Hulst, the grains occasionally collide with each other at high speeds, are raised to a very high temperature and evaporate. The evaporation of iron and other refractory substances will be much less rapid than that of water (H_2O), methane (CH_4), and ammonia (NH_3). Thus there will be a tendency for atoms of iron and the other metals to concentrate in the grains, with relatively less metal than carbon, nitrogen, or oxygen remaining in the gas.

Only a moderate increase in the ratio of grains to gas is needed to explain the difference in composition between primeval and cloud stars. If half of the iron atoms and a fourth of the carbon, nitrogen, and oxygen atoms are locked up in the grains, then an increase by five in the ratio of grains to gas will double the ratio of carbon, nitrogen, and oxygen to hydrogen and triple the ratio of iron to hydrogen, in rough agreement with the preliminary observational evidence on the differences between cloud stars and primeval stars. Since most of the interstellar matter is in the form of hydrogen, this concentration would not change the total density appreciably. It is probably not sufficient for the grains to be entirely concentrated in the clouds of gas observed by Adams and analyzed by Strömgren; since these clouds already contain at least half the mass of the interstellar medium, a concentration of all the grains there would increase the ratio of grains to gas by at most a factor of two. We shall assume that within the various clouds the grains are pushed into the denser, cooler regions which subsequently condense into stars.

At one time I believed that the relative number of grains might become so high in this process of concentration that the value of l for gravitational condensation might be decreased. In view of recent evidence on the relatively slight difference in composition between primeval and cloud stars, this view is no longer tenable, and we must assume that the relative concentration of grains never becomes very large. Probably turbulent motions within a cloud prevent the grains from concentrating entirely in the densest region of the cloud under the influence of radiation pressure.

FROM PROTOSTAR TO STAR

It might be supposed that once the theorist has produced a prestellar globule, with a sufficient gravitational field to hold itself together, his task is over, and that the subsequent contraction of this protostar will

follow as a matter of course. While this supposition can perhaps be defended, in view of the strong circumstantial evidence for star formation, a detailed study shows that the possibility of this last stage is in fact very difficult to establish. In particular there is one major obstacle that the protostar must somehow circumvent if it is to contract into a star. This obstacle arises from the rotational momentum of the protostar.

The conservation of angular momentum will make the rotational velocity inversely proportional to the radius of the condensation. If the radius decreases from about a parsec down to a few solar radii, this decrease amounts to a factor of about 10^7. Unless the original rotational velocity were no greater than a centimeter per second, a remarkably low value for a cloud moving through space at several kilometers a second, the contracting protostar would spin so fast that it could never contract all the way into a star.

Von Weizsäcker has suggested that turbulent motions may carry most of the angular momentum out to infinity, leaving much of the mass behind. The present author has suggested that rotation of a protostar in a weak magnetic field (about 10^{-12} gauss) would generate eddy currents that would slow down the rotation, transferring the angular momentum to other regions of the Galaxy. It is possible that either of these processes, or some combination of both of them, may provide the solution to the angular momentum problem.

Magnetic fields, if unimportant initially will not impede the condensation at any subsequent stage. Since the magnetic lines of force are frozen into the material, the magnetic flux $\pi r^2 B$ through the protostar will remain constant throughout the contraction, where r is the radius of the condensation, and B is the average field in the condensation. Hence B will vary as $1/r^2$, the magnetic energy density, as $1/r^4$, and the total magnetic energy, as $1/r$. The negative gravitational energy also varies as $1/r$. Thus if the gravitational energy much exceeds the magnetic energy at the beginning, a necessary condition for the gravitational contraction of the protostar to begin, the magnetic energy will be unimportant at all stages in the contraction.

If the conductivity of the protostar remained high throughout the contraction, B would increase by a factor of about 10^{14} giving a field strength in the neighborhood of 10^8 gauss for the resultant star. However, it seems likely that at some intermediate stage in the contraction the conductivity will decrease sharply. Ionization produced by ultraviolet radiation will fall off markedly as the protostar becomes opaque, and until the kinetic temperature rises above 1,000° K there will be negligible thermal ionization. Cosmic rays will produce some free electrons, but it is still uncertain whether cosmic rays have an appreciable abundance in interstellar space, and they might fail to penetrate the strong magnetic field of the protostars. In view of these uncertainties no definite calculations seem appropriate, but the occurrence of smaller magnetic fields in stars need occasion no surprise.

There is one last evolutionary stage to be considered. After the protostar has condensed to the stellar state, with its internal temperature increasing under continual compression until atomic energy begins to be released, the process of evolution slows down. The gradual conversion of hydrogen into helium we have already discussed. This is a relatively slow process, except for the very brightest stars. Another gradual change, whose importance has recently been pointed out by Schwarzschild, is the increase of the star's velocity produced by encounters with interstellar clouds. It appears that this effect may explain the systematic observed increase of velocity with age among the cloud stars.

As pointed out by Jeans and Chandrasekhar, encounters between separate stars have a negligible effect on stellar velocities within 10^9 years. It does not seem to have been generally realized that the individual clouds, with a typical mass much greater than a stellar mass, have a much greater effect, even though the total amount of matter in the clouds is about the same as in the stars. Essentially, the effect of a few encounters with clouds of large mass is much greater than the effect of many encounters with less massive stars.

While the detailed analysis of this effect is complicated, the essential results may be summarized briefly. Let a group of stars

formed at a certain time have a root mean square radial velocity v_c in the galactic plane. This velocity may be identified with the root mean square radial velocity of the denser interstellar clouds, about 10 km/sec. The few clouds of very high velocity are generally less dense than the slower clouds and are presumably much less likely to condense into stars. If equipartition existed, the stars and clouds would have the same kinetic energy, and the stars, with much smaller masses, would be moving more rapidly. Collisions will attempt to approach this equipartition, and while they cannot go very far in this direction in the time available, they will increase v, the root-mean-square cloud velocity at any time. If we make the simplifying assumption that the velocities of clouds and stars are both Maxwellian, then the change of v with time is given by

$$\frac{dv}{dt} = (6\pi)^{1/2} (\log \beta) n_c m_c^2 G^2 \frac{v_c^2}{v(v^2 + v_c^2)^{3/2}} \quad (4)$$

where n_c is the number of clouds per cm^3, m_c the mass per cloud, v_c the root-mean-square cloud velocity (in three dimensions), G the gravitational constant, and $\log \beta$ is a somewhat uncertain parameter which we may set equal to 3.

On the basis of this equation the small interstellar clouds, whose mass is perhaps a hundred suns, do not have an important effect. However, large cloud complexes are observed in the Milky Way, each with an individual mass possibly as great as 10^6 suns. If the mean distance between these cloud complexes in the galactic plane is assumed to be about 350 parsecs, then v will increase from 10 to 20 km/sec in about 10^9 years according to equation (4). For comparison with this result, observed root mean square radial velocities for stars of different spectral types are listed in Table 4, taken from recent results by Vyssotsky and Nordström. The table lists the root mean square velocities in one coordinate in the galactic plane (averaged over both directions in this plane). It is evident from these data that stellar velocities do in fact increase from type B (young stars) to type F (stars of all ages) in about the manner predicted by theory. The further increase of velocity for later spectral types cannot be explained on this basis, since stars of type F and later can shine for 3×10^9 years, and stars of all ages should be present equally in these late spectral types. It appears that the greater velocity of the cooler, less luminous stars on the main sequence results from the admixture of primeval high velocity stars, which cannot readily be eliminated from the data, and which begin to outweigh the cloud stars at these low luminosities.

Evidently the present picture is uncertain in many respects, and many details will unquestionably be changed within the next few years. However, the broad difference in origin between cloud stars and primeval stars which has been sketched here seems a useful working hypothesis. One may hope that additional research will soon indicate how far this present view of star formation may be accepted as an adequate description of reality.

TABLE 4.—ROOT MEAN SQUARE RADIAL VELOCITIES IN THE GALACTIC PLANE

Spectral type	Velocity in km/sec
Main sequence	
O-B5	9.7
B8-B9	12.0
A0-A9	14.9
F0-F9	19.9
F5-G0	22.6
G0-K6	25.3
K8-M5	31.6
Giant stars	
K0-K9	20.5
M0-M9	23.3

ENTOMOLOGY.—*New American chinch bugs (Hemiptera: Lygaeidae).* CARL J. DRAKE, Iowa State College.

The members of the genera *Blissus* Klug, *Neoblissus* Bergroth, and *Parablissus* Barber are commonly called chinch bugs. So far as known they are entirely grass-feeding insects. Several of the species are serious pests of grasses, small grain, and corn. *Blissus leucopterus* (Say) of North America ranks very high among the most injurious insect pests of corn and small grain, particularly in the States of the Midwest where corn and small grain are extensively cultivated. Grasses in United States, West Indies, and Central America are attacked by four or five different kinds of chinch bugs. Serious outbreaks of *Blissus* occur at irregular intervals, depending largely upon weather conditions.

The present paper contains the descriptions of two new species of *Blissus*, one new *Neoblissus*, and notes on several other species. The genera *Neoblissus* and *Parablissus* are peculiar to the Americas, whereas *Blissus* is represented in most of the major land divisions of the world. So far as known the species of *Neoblissus* are myrmecophilous, feeding and breeding on grasses growing inside of chambers of the nests of the vicious ant *Solenopsis saevissima* Sm. *N. weiseri*, a new species described herein, also inhabits the nests of the same species of ant in Argentina. Both species live as guests in the nest and receive no apparent care from their host. The bugs are free to wander about in the chambers, or even to leave the nests. The nymphs are not known to occur outside of the nests.

The species of *Neoblissus* are widely distributed and fairly common in ant nests; more than 1,000 nymphs and imagoes have been collected in a single nest. Nymphs of all stages and adults are found in large numbers in the nests during the growing period, whereas adults are most abundant late in summer and in winter. The adults overwinter in large numbers in the lower chambers of the nests. The late Dr. Carlos Bruch (*loc. cit.*) of La Plata has published an interesting account of *Neoblissus* in the nests of *Solenopsis saevissima*.

Unless otherwise stated, the types of the new species are in my personal collection.

Apterous and macropterous forms of two chinch bugs, *Blissus mixus* Barber (Fig. 2) and *B. iowensis* Andre (Fig. 1) are illustrated. The latter is found on the crown of bluestem grasses, often slightly below the surface of the ground.

Blissus hirtus Montandon

Blissus hirtus Montandon, Ann. Soc. Ent. Belg. **37**: 405. 1893.

In Montandon's collection there are no examples of this chinch bug from the type locality, Hazleton, Pa., M. Dietz. However, his collection contains two specimens of this insect from "*Canada, L. Provancher*," which are as hairy as typical *hirtus*. Specialists in Hemiptera are not fully in accord regarding the status of *B. hirtus* Montandon. Some workers consider it as a longly hairy variety of *B. leucopterus* (Say), whereas others treat it on the species level. It is at least a good geographic race or subspecies and not nearly so widely disseminated as typical *B. leucopterus*. At irregular intervals *B. hirtus* is a serious pest of grasses in lawns and golf courses in the northern States from Minnesota east clear across Pennsylvania and New York, and then north deep into Canada.

Blissus pulchellus Montandon

Blissus pulchellus Montandon, Ann. Soc. Ent. Belg. **37**: 406. 1893.

The type series of *B. pulchellus* in Montandon's collection contains only two specimens, each carded on a separate rectangular card and mounted on separate pins. The first pin bears (1) carded brachypterous female, (2) locality label "Costa Rica, Buenos Aires, A. Pittier," and (3) species label "*Blissus pulchellus* Montd." in Montandon's own handwriting. The other pin bears (1) a carded long-winged female and (2) the same locality label and collector. It seems that Buenos Aires is the name of a small village in Costa Rica. The apterous female is designated here as the type and the other female as a paratype. Both specimens are in fairly good condition and deposited in the Muzeul National de Istoria Naturala "grigori antipa," Bucuresti. The following notes are based on the brachypterous type.

Short-winged female: Length, 2.75 mm; width, 0.88 mm. Head black, slightly pruinose, with some short, pale, decumbent hairs; width across eyes, 0.60 mm; wider across eyes than median length (48:42). Antennae moderately long, shortly pilose, yellowish brown with apical segment dark fuscous; formula—I, 12; II, 25; III, 21; IV, 35. Pronotum black with pruinose in front, nearly flat above, almost rectangular in outline with sides becoming a little narrower anteriorly and more rounded on front corners, wider at base than median length (68:43). Abbreviated hemelytra almost attaining middle of abdomen, whitish with dark fuscous patch beyond middle, rather broadly rounded at apex, the veins with some erect pale hairs; membrane short, pale. Scutelum black. Abdomen above brownish, beneath bluish black. Legs yellowish brown, clothed with short pale hairs.

In the alate paratype the hemelytra do not quite reach to the apex of the abdomen, leaving most of the connexiva exposed. Length 2.90 mm.

Specimens of *B. pulchellus* from La Ceiba, Honduras, taken on *Panicum*, by F. S. Dyer, U. S. National Museum, agree very closely with the type and have been labeled by Dr. R. I. Sailer and the writer as "*comp. with type.*" Others in the National Museum were taken on the roots of *Panicum purpurea*, Los Sabanas, Panama, James Zetek.

Blissus brasiliensis, n. sp. Fig. 3

Elongate, rather densely longly pilose, moderately shaggy, blackish, with abdomen reddish brown, the head, anterior part of pronotum and abdomen beneath bluish. Head a little wider across eyes than median length (56:45), with pale hairs more or less erect; tylus fuliginous; eyes small, reddish, with a few short hairs. Antennae moderately long, rather densely shortly pilose, yellowish brown with the terminal segment (also sometimes third and apex of second) dark fuscous; formula—I, 10; II, 22; III, 30; IV, 37. Rostrum testaceous, extending between middle coxae. Venter reddish brown, bluish.

Macropterous form: Pronotum subquadrate, slightly narrowed anteriorly, widest across humeral angles, anterior pruinose part finely punctate; hind part black, punctate, width at base much wider than median length (95:65). Abdomen almost parallel-sided. Hemelytra not quite reaching apex of abdomen, whitish, the apical angle of corium black-fuscous. Length, 3.60 mm; width, 1.00 mm.

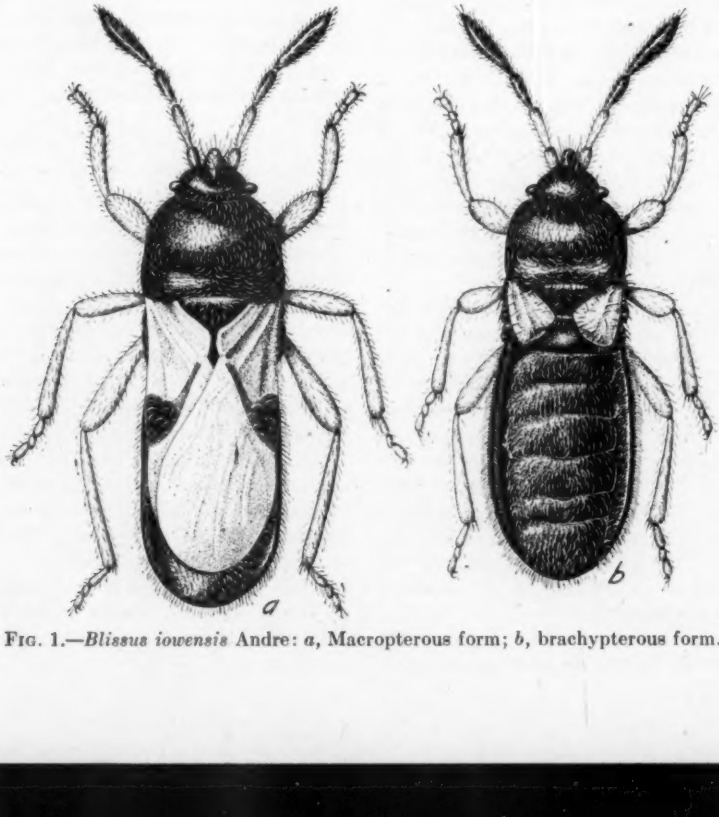


FIG. 1.—*Blissus iowensis* Andre: *a*, Macropterous form; *b*, brachypterous form.

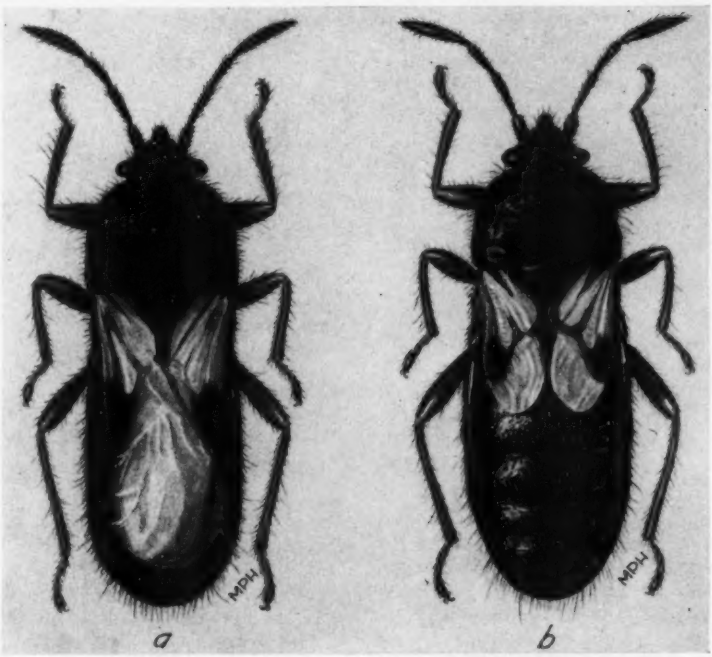


FIG. 2.—*Blissus mixus* Barber: *a*, Macropterous form; *b*, brachypterous form.

Brachypterous form: Abbreviated hemelytra about three-fifths as long as abdomen, whitish with dark patch a little smaller than in long-winged form. Entire insect also smaller than macropterous form. Length, 3.00 mm.

Type, macropterous male and *paratype* brachypterous male, Corumba, Brazil. *Allotype*, macropterous female, Santarém, Brazil.

The much shorter antennae separate this species at once from *M. penningtoni* Drake, and it is distinctly smaller with much longer pubescence or short hairs than *B. richardsoni* Drake.

Blissus yumana, n. sp.

Elongate, black, moderately shaggy, the abdomen reddish brown; hairs whitish, erect or partly decumbent; head, anterior half of pronotum and abdomen beneath bluish. Head wider through eyes than median length (60:60), the tylus brownish. Antennae long, longly pilose, testaceous, the fourth and sometimes the fifth segment dark fuscous; formula—I, 20; II, 40; III, 32; IV, 52. Rostrum testaceous, extending between hind coxae. Legs testaceous, clothed with short pale hairs. Pronotum much wider than long (100:62), finely punctate, the sides with front corners more rounded; hind lobe considerably flattened.

Macropterous form: Hemelytra not quite attaining apex of abdomen, the dark fuscous spot in apical angle of corium extending a little into membrane; membrane with veins distinct. Length, 4.40 mm; width, 1.24 mm.

Brachypterous form: Hemelytra about three-fifths as long as the abdomen, with dark spot in apical angle of corium about the same size as in long-winged form; membrane short, subtransparent, narrowly rounded apically. Length, 4.20 mm.

Type (macropterous male), *allotype* (brachypterous female), and 6 *paratypes*, Yuma, Ariz., E. D. Ball.

The longer antennae and longer body separate this species at once from *B. leucopterus* and other North American members of the genus.

Blissus richardsoni Drake

Blissus richardsoni Drake, Notas Mus. La Plata **5**: 224, fig. 1. 1940.

Described from a single specimen, collected

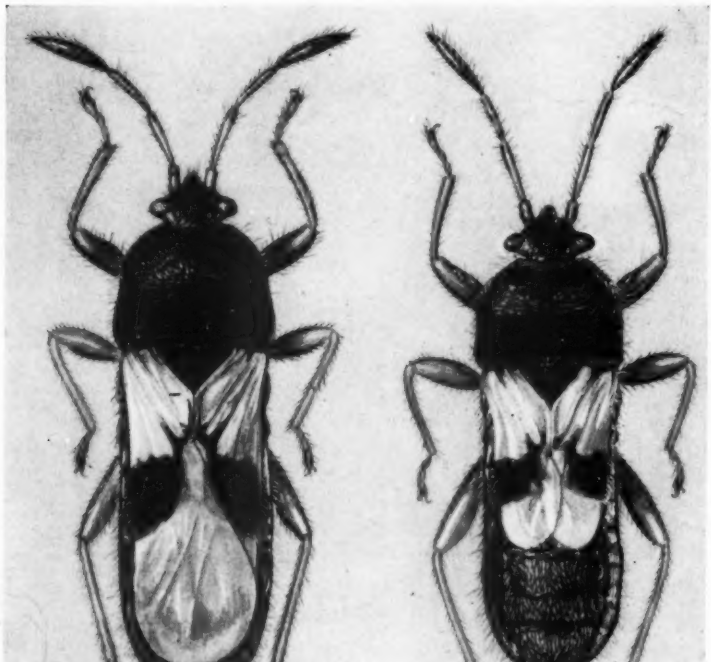


FIG. 3.—*Blissus brasiliensis*, n.sp.: *a*, Macropterous form; *b*, brachypterous form.

near Buenos Aires, Argentina. The larger and more robust size and clothing of very short hairs separate this insect at once from other Brazilian and Argentine species. The fourth antennal segment is also much longer and stouter. In addition to the type, there are two females (long- and short-winged) from Chapada, Brazil. The brachypterous form is shorter than the macropterous, and the abbreviated wings do not quite reach the middle of the abdomen. The short hemelytra are moderately long, obliquely rounded at apices, reaching almost to the apex of third visible tergite, whitish testaceous on basal half, thence dark fuscous; membrane is short, fumose; veins are moderately prominent. The pronotum is considerably flattened. Antennal formula: I, 12; II, 32; III, 26; IV, 60. The eyes bear a few short hairs.

Neoblissus hygrobius (Jensen-Haarup)

Mendocina hygrobia Jensen-Haarup, Ent. Medd. **13:** 210, fig. 1. 1920.

This chinch bug was described from a brachypterous male, taken in the Province of Mendoza, Argentina, by A. C. Jensen-Haarup, who wrongly treated it as a member of the "shore bug" family Aeophilidae and thus found it necessary to erect a new genus for its reception. A study of the description and figures shows that *hygrobia* belongs to either the genus *Blissus* or *Neoblissus* of the family Lygaeidae. At the moment it seems advisable to synonymize the genus *Mendocina* Jensen-Haarup with *Neoblissus* Bergroth.

N. hygrobius (Jensen-Haarup) is very similar and closely related to *N. parasigaster* Bergroth. An examination of the type of the former may prove that the two names apply to the same species. Size, shape, length of brachypterous wing pads, and color seem to be identical. There may be a little difference in the antennal formula. However, it will be necessary to examine the type of *N. hygrobius* to establish its true specific status.

The genus *Neoblissus* Bergroth was erected for the reception of a myrmecophilous chinch bug found feeding and breeding in the nests of ants (*Solenopsis saevissima*) in Brazil. The genus is very closely allied to the genus *Blissus* and is distinguished largely by the very short wing pads with wide and subtruncate apex in the brachypterous form. So far as known the species of *Neoblissus* feed and breed on grasses grown in the chambers in the nests of ants. Until more is known about myrmecrophilous chinch bugs, it seems best to leave *Neoblissus* stand as a valid genus. Another species of chinch bug found inhabiting ant nests in Argentina is described below as new to science.

Neoblissus parasigaster Bergroth

Neoblissus parasigaster Bergroth, Entom. Zeit. Wien **23:** 253. 1903.
Neoblissus parasigaster Bruch, Physis **3:** 146. 1917.
Neoblissus parasigaster Bruch, Physis **4:** 53. 1918.
Neoblissus parasigaster Drake, Notas Mus. La Plata **5:** 226, fig. 3. 1940.

In the macropterous form the hemelytra are whitish, with apical angle of corium blackish fuscous, and do not reach the apex of the abdomen. The dark fuscous patch varies in size, sometimes including as much as one-half of the corium. It is widely distributed in Argentina and Brazil, where it lives as a guest in large numbers (both nymphs and adults) in the underground chambers of vicious ant nests (*Solenopsis saevissima*).

It feeds and breeds on the grasses growing on the inside of the chambers and hibernates during winter in the lower chambers. It is apparently undisturbed by the ants and is free to move in the cavities and to leave the nest. Bruch reports finding more than 1,000 chinch bugs in a single nest. The nymphs (all stages) are extremely abundant during summer, the adults during the winter months. Dr. Bruch's preliminary (*loc. cit*) account of the relationship is very interesting, and it is unfortunate that he was never able to complete his studies.

Neoblissus weiseri, n. sp.

Brachypterous form: Moderately large, moderately shaggy, head and pronotum brownish black to black; abdomen reddish brown; hairy clothing moderately long fine, dense, whitish testaceous. Legs yellowish brown, clothed with short pale hairs. Antennae moderately long, shortly pilose, the terminal segment often dark; formula—I, 12; II, 25; III, 20; IV, 40. Head across eyes and median length almost subequal; tylus brownish. Rostrum testaceous, its tip reaching to base of abdomen. Orifice brownish, with large canal. Scutellum brownish to black, twice as wide as long, punctate. Hemelytral pads short, reaching on the outside to hind margin of third visible tergite; posterior margin subtruncate, very strongly oblique (or feebly rounded), within being whitish, dark in apical corner or corium, with veins brownish; veins testaceous or brownish and hairy.

Pronotum finely punctate, much wider than long (92:52), with sides becoming slightly narrower anteriorly and more rounded at anterocorners. Abdomen moderately shaggy, clothed with pale hairs, beneath being reddish brown to black, moderately hairy. Length, 3.20 mm.; width, 1.25 mm.

Macropterous form: Hemelytra variable in length, generally a little shorter than abdomen, sometimes considerably shorter leaving the last two tergites exposed; apex of corium with blackish spot. Length, 3.00–3.15 mm.; width, 1.25 mm.

Type (male) and *allotype* (female), both brachypterous, Province of Entre Ríos, Fives Lille, Santa Fé, Argentina, taken by Weiser, in La Plata Museum, Argentina. Paratypes, apterous and macropterous forms, taken with types, in the nests of the vicious and almost vicious omnivorous ants, *Solenopsis saevissima*.

Easily distinguished from *B. parasigaster* Bergroth by its smaller size and shorter antennae; and the hemelytral pads are slightly and obliquely truncate apically. The wing-pads of *B. parasigaster* are shorter and feebly obliquely truncate and very wide at apex.

ENTOMOLOGY.—*New species of chrysomelid beetles of the genera* Trirhabda *and* Disonycha. Doris H. Blake, Arlington, Va.

The following new species of *Trirhabda* and *Disonycha* form an addition to my revisions of those genera in 1931[1] and 1933,[2] respectively. The specimens from which they were described, with one exception, had been set aside from the regular collection by H. S. Barber as new and came to light only after his death.

Trirhabda geminata Horn

Figs. 2, 4, 6, 9

Trirhabda geminata Horn, Trans. Amer. Ent. Soc. **29**: 68. 1893.

Trirhabda nigrohumeralis Schaeffer, Bull. Brooklyn Inst. Arts and Sci., **1**: 170. 1905.

In my revision of the genus *Trirhabda* I stated that the "pale forms of *geminata* are sometimes difficult to distinguish from *nigrohumeralis*" but "in general *nigrohumeralis* is smaller . . . and the aedeagus quite unlike that of *geminata*, being small, tapering and rounded at the tip." At that time I did not have specimens of Schaeffer's types of *nigrohumeralis* and did not realize that the aedeagus that I was describing was from a specimen outwardly like *nigrohumeralis* but quite unlike that species in its genitalia. From labels in the collection I have found that H. S. Barber, on acquiring Schaeffer's collection and dissecting a male of that species, at once saw that what I described was really a new species. However, he does not appear to have suspected that *nigrohumeralis* itself is simply a color form of *geminata*. I am forced to this conclusion after examining specimens from many localities in California, Arizona, New Mexico, and even Texas. Horn gave as type localities "San Diego, California and Arizona." Specimens from near the coast are darker in their markings than many inland specimens, although some from Nogales and Tucson, Ariz., are fully as dark. Others from those localities are of the coloring that Schaeffer described for *nigrohumeralis* with "unicolorous pale elytra" having "an elongate narrow black humeral spot." Dissection of these specimens reveals an aedeagus like that of *geminata*. A still paler and smaller series of specimens from near Presidio, Tex., taken on *Brickellia* shows a similar aedeagus. It appears that this species as it occurs eastward across the country grows smaller and paler in coloring. Specimens were taken by Hubbard and Schwarz at St. Rita and Nogales on *Brickellia*, and also in 1945 by an unknown collector on this food plant at Nogales. Other specimens at Nogales were taken on lettuce (collector unknown). At Cataline Springs, northeast of Tucson, they were taken by Hubbard and Schwarz on *Encelia*, and on guayule, near Tucson, by an unknown collector. The localities for *T. geminata* (including the paler forms) in the U.S. National Museum are: *California:* Claremont, Baker Coll.; *Arizona:* Bright Angel, Camp Verde, H. Brisley; Cataline Springs, Hubbard and Schwarz; Huachuca Mountains, Schaeffer Coll.; Nogales, Oracle, Hubbard and Schwarz; Palmerly, Cochise County, Schaeffer Coll.; Sta. Rita Mountains, Hubbard and Schwarz; *New Mexico:* Jemez Mountains, John Woodgate; Las Vegas, Barber and Schwarz; *Texas:* Near Presidio, collector unknown.

Trirhabda schwarzi, n. sp.

Fig. 7

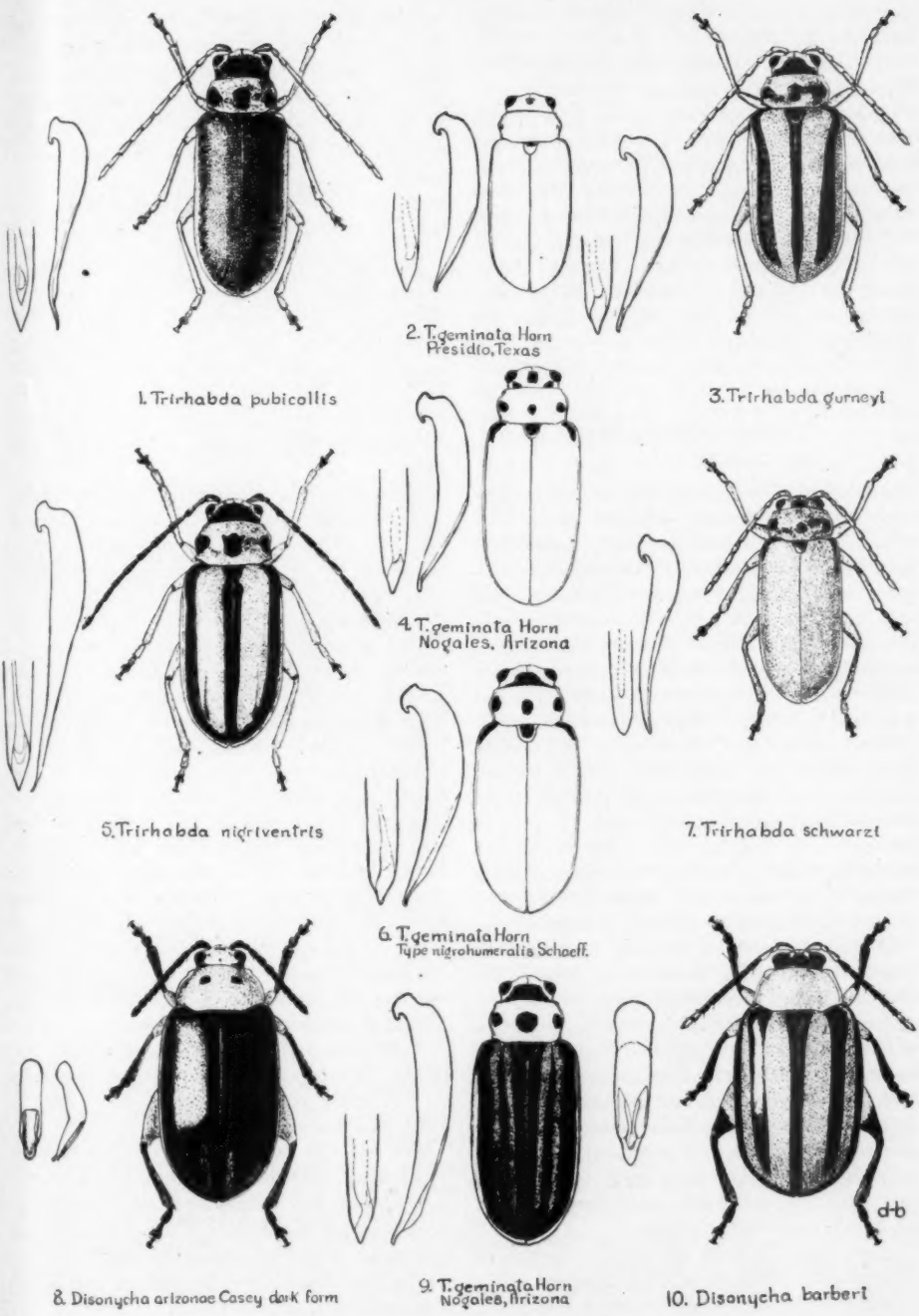
Trirhabda nigrohumeralis Blake (not Schaeffer, 1906), Proc. U. S. Nat. Mus. **79** (art. 2): 30, 31. 1931.

Between 4.5 and 7.5 mm in length, elongate oblong, pale yellow-brown, finely pubescent, the head with an oblong dark spot, mouthparts pale; three dark pronotal spots; scutellum bicolored, the elytra with a dark humeral streak, body beneath entirely pale, antennae usually pale, claw joint sometimes a little darker.

Head with a dark oblong spot down the occiput, mouthparts pale, densely and obsoletely punctate down to tubercles with a depressed median line, from tubercles down shiny and impunctate. Antennae usually pale brownish, not at all piceous. Prothorax about twice as wide as long, depressed on each side, alutaceous, with coarse punctures, pale brown with three small spots. Scutellum partly dark. Elytra pale brown with a darker humeral streak fading out down the side. Body beneath entirely pale, legs pale, except sometimes the claw joint a little darker. Length 4.6–7.4 mm; width 2–3 mm.

Type male and 41 paratypes, U.S.N.M. no. 61126. 2 paratypes in M.C.Z., collected at Ash-

[1] Proc. U. S. Nat. Mus. **79** (art. 2): 1–36. 1931.
[2] Proc. U. S. Nat. Mus. **82** (art. 28): 1–66. 1933.



FIGS. 1–10.—Species of *Trirhabda* and *Disonycha*

fork, Ariz., by H. S. Barber and E. A. Schwarz on June 17, 1901.

Other locality.—Prescott, Ariz., collected by Barber and Schwarz on June 19, 1901.

Remarks.—This species is outwardly well-nigh indistinguishable from the pale forms of *T. geminata* Horn (*nigrohumeralis* Schaeffer) and was the species figured and erroneously believed to be *nigrohumeralis* in my revision of the genus in 1931. The aedeagus is not at all like that of *geminata*, and there are a few minor color differences that appear to be constant—the antennae and mouthparts are pale, not piceous, and the claw joint alone is dark, whereas in *geminata*, except in palest forms, the last two tarsal joints are usually dark.

Trirhabda pubicollis, n. sp.

Fig. 1

About 7 mm in length, elongate oblong, densely and somewhat rugosely punctate, head, pronotum, and elytra with fine short pubescence; pale yellow-brown, the head with a deep metallic-green band extending from occiput to tubercles except for a narrow pale area about eyes; pronotum with three large irregularly shaped piceous spots, elytra metallic dark green except for a narrow yellow border, body beneath, legs and antennae pale, claw joint deeper brown.

Head densely and rather shallowly punctate over occiput and upper front with a median impressed line, finely pubescent, area above tubercles except for a narrow area about eyes entirely dark metallic green, labrum piceous edged. Antennae pale reddish brown except for a deeper brown basal joint, unusually long and slender, fourth joint about twice as long as third. Prothorax about twice as wide as long with nearly straight sides (viewed from above); depressed across the middle, especially on the sides, and coarsely punctate, surface shining, not at all alutaceous and with moderately dense pale pubescence, pale with three large, irregularly shaped piceous spots. Scutellum dark. Elytra deep metallic green with a pale yellow brown border, densely and moderately coarsely punctate and covered with fine pale pubescence. Body beneath and legs pale, the claw joints alone deeper brown. Length 7 mm; width 2.4 mm.

Type male U.S.N.M. no. 61127, collected at El Paso, Tex., May 2, collector unknown.

Remarks.—Only a single specimen is at hand, but this one is distinctly unlike any other described from north of Mexico. It may well be a Mexican species but apparently is not described. The prothorax is unusual in being conspicuously pubescent and short. The aedeagus too is distinctive with its long tapering tip.

Trirhabda gurneyi, n. sp.

Fig. 3

Between 6 and 7.5 mm in length, elongate oblong, faintly shining, especially on the prothorax, with finely pubescent elytra, pale yellow-brown, the head with a wide, dark, occipital band curving down front, prothorax with the usual three dark spots, scutellum dark, elytra with piceous sutural and lateral vittae, not united at the apex, body beneath, antennae and legs pale.

Head coarsely punctate over occiput and down to frontal tubercles, with a median impressed line, pale with a dark band across occiput, curving down the front, mouthparts usually dark. Antennae as a rule pale, never deep piceous. Prothorax not quite twice as broad as long, with slightly angulate sides, depressed on either side, shining, not at all alutaceous, and more or less coarsely punctate, pale with three medium sized black spots, the middle one often shield shaped. Scutellum usually entirely dark, in 2 of the 14 specimens somewhat paler toward apex. Elytra densely and moderately coarsely punctate, the punctures not confluent, and with short fine pubescence; pale yellow brown with a narrow sutural and not very wide lateral vitta, these not uniting at apex, the sutural one becoming narrow at apex so as to darken only the sutural edges, in one specimen the lateral vitta fading out from the middle to apex. Body beneath and legs pale, the claws somewhat deeper in coloring. Length 6–7.5 mm; width 2.6–3 mm.

Type male and 11 paratypes, U.S.N.M. no. 61128. Two paratypes in M.C.Z., collected by A. B. Gurney at Indian Springs, Nev., June 5, 1949, on *Franseria*.

Remarks.—In coloring this species resembles somewhat *T. adela* Blake, except that it is always pale beneath and smaller with less densely pubescent elytra. It has also a shiny, not alutaceous prothorax. It differs from *T. nitidicollis* in not having the vittae joined at the apex and in the differently shaped prothorax.

Trirhabda nigriventris, n. sp.

Fig. 5

Between 6 and 9.5 mm in length, elongate oblong, finely punctate, with short, fine pubescence, head with a broad black plaga curving down over front, thorax shiny, 3-spotted, elytra with narrow sutural and lateral vittae almost always uniting at apex, frequently the lateral vitta having a paler trace of vitta as an offshoot near the apex, breast and abdomen dark.

Head with a median impressed line, densely and not very coarsely punctate over front, a broad dark occipital band curving down front, mouthparts with dark edging. Antennae long and slender, the basal joints with pale edging, distal joints entirely dark. Prothorax not quite twice as broad as long with slightly arcuate sides, depressed across, especially on the sides, shiny, more or less coarsely punctate, with three black spots, the middle one tending to be shield shaped. Scutellum usually entirely dark. Elytra densely but not very coarsely punctate, with short fine pubescence, sutural dark vitta nearly always uniting at apex with lateral vitta, the lateral vitta frequently having at apex a decurrent paler brown vitta running up, sometimes to the middle of the elytra. Body beneath with breast and abdomen, except at the tip, dark, legs pale, except the darker claw joint. Length 6–9.5 mm; width 2.6–3.5 mm.

Type male and 90 paratypes, U.S.N.M. no. 61129. Four paratypes in M.C.Z.; 5 paratypes in British Museum, taken on sagebrush, *Artemisia tridentata*, August 1, 1938, by O. V. Smith at Aztek, N. Mex.

Remarks.—The dark ventral surface and shiny prothorax distinguish this species from *T. lewisii* Crotch. It is one of the few larger western species with a dark undersurface.

Disonycha barberi, n. sp.

Fig. 10

From 5.4 to 6.6 mm in length, oblong oval, shining, pale yellow, the head with a broad dark occipital band extending in a point down the front and about the eyes and sides, the elytra with a sutural and marginal dark vitta uniting at apex and a median vitta, legs dark at apex of femora and the tibiae and tarsi entirely dark, beneath with the breast dark. Eyes unusually large, antennae dark with the tip paler.

Head shining, the polished dark occipital band finely punctate on the occiput and front and extending in a peak down to tubercles, also about the eyes and down the side of the head, the mouthparts dark; eyes unusually large, the interocular space being less than half the width of the head, a fovea on each side near eye composed of punctures; tubercles pale and well marked, carina between antennal sockets not very wide or produced but rounded. Antennae dark with the three basal and 2 apical joints more or less pale. Prothorax about twice as wide as long at base with rounded sides, somewhat depressed over the scutellum, entirely pale with very faintly punctate surface, shining. Scutellum dark, triangular. Elytra shining, more distinctly punctate, pale with a moderately wide sutural and marginal vitta joined at apex, median vitta moderately wide, epipleura wide and dark but diminishing and vanishing before the apex. Body beneath with the breast more or less darkened, the apices of the anterior pairs of femora narrowly and those of the posterior femora more widely dark, the tibiae and tarsi dark. Length 5.4–6.6 mm; width 3–3.3 mm.

Type male and 20 paratypes, U.S.N.M. no. 61130. Two paratypes in M.C.Z., 1 paratype in British Museum, collected at Brownsville, Tex., four specimens on September 16, 1939, on *Condalia obovata* and the rest in June 1945 and September 1944 by J. D. Smith, who reared them from *Phaulothamnus spinescens*.

Other localities.—San Bonito, Tex., on corn foliage, March 27, 1945; Sebastian, Tex., April 24, 1945; 1 specimen trapped at airport, Brownsville, June 6; 1 specimen taken from the cabin of a plane "in Mexico," June 26, 1947.

Remarks.—This species had been labeled by Mr. Barber with two different new specific names, the first one from its resemblance to *D. glabrata* (Fabricius), the second from its food plant. Both names are somewhat awkward-sounding, and so I propose to name it after Mr. Barber whose glee on discovering it I well remember. In general markings it resembles closely *D. glabrata*, but the unusually large eyes and different pattern of the head markings at once distinguish it. None of the specimens has any pronotal dark spots such as are usual in *D. glabrata*. Both larvae and eggs were sent in by J. D. Smith, who reared it from *Phaulothamnus spinescens*.

Disonycha arizonae Casey

Fig. 8

Some years ago Dr. E. C. Van Dyke sent me four specimens (three females and one male) of a *Disonycha* from the collection of the California Academy of Sciences, with the label Elmwood, Tenn., Fenyes Coll. At first sight it seemed to be something new, but the label reminded me of a series in the U. S. National Museum with the same locality label that were typical specimens of *D. arizonae* Casey, and on comparison I found these four to be simply a dark color form of that species. This was corroborated by examination of the male genitalia. In all four specimens the elytra were deep reddish brown or piceous with a narrow pale margin, and in all four there was a faint trace of vittation at the apex, in the darkest specimen, only a tiny pale spot but in the others, showing very faintly, two pale vittae.

ZOOLOGY.—*Geographical distribution of the nemerteans of the northern coast of the Gulf of Mexico as compared with those of the southern coast of Florida, with descriptions of three new species.* WESLEY R. COE, Scripps Institution of Oceanography.[1] (Communicated by W. L. Schmitt.)

Up to the present time no published information has been available relative to the nemerteans of the areas covered by this report. Consequently it has been uncertain whether the nemertean fauna might be found to consist principally or wholly of species identical with those of the Atlantic coast or whether the more typically tropical or subtropical species would be included. Nor was it known whether any or many apparently endemic forms might be present.

Twenty-two species have now been identified. Sixteen of these are found on the northern coasts of the Gulf and six others in southern Florida. Only two specimens from the deeper, off-shore waters of the Gulf have been obtained by the writer. Both of these belong to either *Lineus* or *Micrura*, but the specimens were not sufficiently well preserved to allow specific analysis. No information is yet available for all that portion of the western Gulf coast south of the Mexican border, or for any locality on the west coast of the Florida peninsula between Franklin County and Key West.

The presumable explanation for the small number of species at present known is that only sporadic efforts have been made toward a complete survey of the littoral fauna of the Gulf. On the Atlantic coast of North America there are 53 known species of nemerteans and on the Pacific coast 95 species. Hence it seems probable that there are many more species now actually living in the Gulf than can be included in this report.

Even on the Atlantic coast the nemerteans have been studied extensively only as far south as New Jersey, and our knowledge of the species living between that State and Florida is based on collections made at widely separated localities. It may therefore be assumed that some, perhaps many, additional species remain to be discovered there.

All except two of the species known from the northern part of the Gulf are also found on the Atlantic coast. Therefore, it seems probable that the nemertean fauna of the northern Gulf coast has in the past been a continuation of that of the Atlantic coast and that it is now a separate fauna that was isolated in Pleistocene times by the Florida Peninsula. To determine whether any of the populations of the two areas are at present continuous, it is essential to obtain additional collections on both sides of the southern half of that peninsula. It is already known that the species found at Pensacola, on the Gulf side, are similar to those found by the writer personally at St. Augustine, on the Atlantic side. The following lists, however, indicate that these two nemertean faunas are separated by an area in which other species predominate.

Because the nemerteans of the northern Gulf coast are generally of different species than those at present known from southern Florida, the species of the two areas will be listed separately.

[1] Contribution from the Scripps Institution of Oceanography, new series, no. 539.

I. GEOGRAPHICAL DISTRIBUTION OF SPECIES AT PRESENT KNOWN FROM THE NORTHERN COAST OF THE GULF OF MEXICO

[Abbreviations indicate: A, Atlantic coast of North America; E, coasts of Europe; G, Northern coast of the Gulf of Mexico; P, Pacific coast of North America; S, southern Florida; W, West Indies; X, at other localities.]

Order 1, PALEONEMERTEA

Family Tubulanidae

Tubulanus pellucidus (Coe), 1895. A, G, P.

Family Carinomidae

Carinoma tremaphoros Thompson, 1900. A, G.

Order 2, HETERONEMERTEA

Family Lineidae

Zygeupolia rubens (Coe), 1895. A, G, P.
Lineus socialis (Leidy), 1855. A, G.
Micrura leidyi (Verrill), 1892. A. G. S.
Cerebratulus lacteus (Leidy), 1851. A, G.

Order 3, HOPLONEMERTEA

Family Emplectonemertidae

Paranemertes biocellata Coe, 1944. G.

Family Carcinonemertidae

Carcinonemertes carcinophila (Kölliker), 1845. A, E. G.
Carcinonemertes carcinophila imminuta Humes, 1942. G, S, W.

Family Prosorhochmidae

Oerstedia dorsalis (Abild.), 1806. A, E, G, P, X.

Family Amphiporidae

Zygonemertes virescens (Verrill), 1879. A, G, P.
Amphiporus cruentatus Verrill, 1879. A, G, P.
Amphiporus ochraceus (Verrill), 1873. A, G.

Amphiporus texanus, n. sp.

This new species represents one of the larger and broader forms of this extensive genus. The type specimen was about 60 mm in length and 6 mm in width after preservation. The length of this specimen is therefore only 10 times the greatest width. The head is narrow, about 2 mm in width, with subterminal mouth and transverse or oblique lateral grooves. There are many small ocelli on each side of the head, although the exact number and arrangement could not be determined in this specimen.

The proboscis is large and extends nearly the entire length of the body. The central stylet is moderately slender and about two-thirds of the length of the relatively massive basis. The latter is nearly rectangular in outline, about four times as long as its diameter, tapering but slightly toward the anterior end and is truncated posteriorly (Fig. 1). In this type specimen the basis measured 0.135 mm in length and from 0.027 to 0.035 in diameter. One of the two accessory pouches contained two well-formed stylets and the other had three, two of which were not yet completed. In this specimen there were 10 rather large proboscidial nerves.

No record is available regarding the color in life, but the specimen preserved in formalin indicated a pale, reddish-brown epidermal pigmentation. The cerebral sense organs are comparatively larger than in most species of the genus. They are situated lateroventrally and a short distance anterior to the brain.

This specimen (U.S.N.M. no. 22965) was collected by B. Earp at Port Aransas, Tex. All the other species of nemerteans at present known from that locality are found also on the North Atlantic coast. Consequently it is uncertain whether this new species is limited to the Gulf of Mexico or whether it may occur also on the Atlantic coast, although it has not yet been found there.

Family Tetrastemmatidae

Tetrastemma candidum (Müller), 1774. A, E, G, P. X.
Tetrastemma vermiculus (Quatr.), 1846. A, E, G.

Order 4, BDELLONEMERTEA

Family Malacobdellidae

Malacobdella grossa (O. F. Müller), 1776. A, E, G, P.

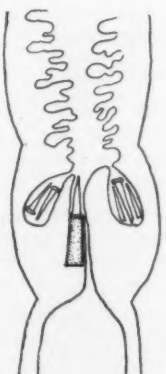


FIG. 1.—*Amphiporus texanus* n. sp.: Outline of stylet apparatus of proboscis.

II. SPECIES AT PRESENT KNOWN FROM SOUTHERN FLORIDA

Order 1, PALEONEMERTEA

Tubulanus floridanus, n. sp.

In the collections from Biscayne Bay, Fla., was one specimen of *Tubulanus* that evidently represents a previously undescribed species. This specimen is very slender, about 40 mm in length and only 1 to 2 mm wide. The color in life is brown, with a series of about 30 very narrow rings of lighter color. Nearly all the rings completely encircle the body. Anteriorly the rings are separated by a distance about equal to the diameter of the body but more posteriorly they are generally more widely separated and irregularly spaced. The lateral sense organs can be distinguished externally but are not conspicuous.

Transverse sections show a rather thick outer epithelium, with a thin, but dense, basement layer and an unusually large median dorsal nerve. The cerebral sense organs are large and highly specialized, with a sensory canal leading laterally to the surface of the epithelium.

Individuals of this species have a superficial resemblance to those of *T. annulatus* (Montague), *T. capistratus* Coe, and *T. nothus* (Bürger) but are without longitudinal lines of contrasting color.

One individual of this species was collected by F. M. Bayer among algae on dock piling on the County Causeway at Miami, Biscayne Bay, Florida. U. S. Nat. Mus. Cat. No. 22251.

Order 2, HETERONEMERTEA

Family Lineidae

Lineus ater (Girard), 1851. S, W.

Lineus stigmatus n. sp.

The collections contained fragments of an undescribed species of this genus, but unfortunately the head was not among them. Nevertheless the markings on the body are so distinctive as to indicate that these fragments could not have belonged to any of the numerous described species. It seems necessary therefore to give as complete a diagnosis of a new species as is possible in the absence of the head.

The fragments have a maximum width of 5 mm, tapering to about 2 mm at the posterior end, indicating that the entire individual would have had a length of 150 mm or more.

The color in life was slaty brown on both dorsal and ventral surfaces, with paired transverse white markings at intervals of 1 to 2 mm on the dorsal surface. Each narrow marking is about one-fifth the diameter of the body in length and the two members of each pair are separated from the margin and from each other by about the same distance (Fig. 2). The markings are limited to the dorsal surface and become irregular and indistinct toward the posterior end of the body. The colors are retained after preservation in alcohol.

Since the anterior end of the body was not obtained, nothing can now be said as to the presence of ocelli, the character of the cephalic grooves or other sense organs or the peculiarities of the nephridia. Transverse sections of the body show an unusually thick cutis with many spiral muscular fibers and a heavily pigmented layer externally.

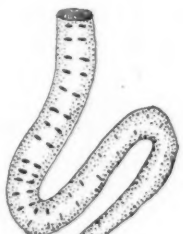


FIG. 2.—*Lineus stigmatus* n. sp.: Outline of posterior portion of body, showing position of white markings. The markings appear to be irregularly spaced, owing to differences in state of contraction.

The paired markings in this species have a superficial resemblance to those of some individuals of *L. geniculatus* (D. Chiaje) in which the white rings are interrupted in the mid dorsal line but in the latter species the rings continue laterally and ventrally. There is also some resemblance to *L. albocinctus* Verrill, recorded from Bermuda and Puerto Rico, although in that species the transverse lines are continuous on the dorsal surface and the ventral surface of the body is whitish.

The species is at present known only from the fragments of one individual collected by G. S. Posner on the shore of Biscayne Bay, Fla. U.S.N.M. no. 22252.

Micrura leidyi (Verrill), 1892. A, G, S.
Cerebratulus fuscus McIntosh, 1873. E, S, X.
Cerebratulus leucopsis (Coe), 1902. S, W.

Order 3, HOPLONEMERTEA

Family Amphiporidae

Carcinonemertes carcinophila var. *imminuta* Humes, 1942. G, S, W.

Family Drepanophoridae

Drepanophorus crassus (Quatr.), 1846. E, P, S, W, X.

SUMMARY

The preceding lists show that many of the species have a remarkably wide geographical distribution already recorded and it may be expected that they will later be found elsewhere. Of the 16 species at present known from the northern Gulf coast, all except *Paranemertes biocellata* and *Amphiporus texanus* are widely distributed on the American Atlantic coast, and four of them, namely, *Tubulanus pellucidus*, *Zygeupolia rubens*, *Zygonemertes virescens*, and *Amphiporus cruentatus*, occur also on the Pacific coast but not in Europe; two others, *Carcinonemertes carcinophila* and *Tetrastemma vermiculus*, are found on American Atlantic and European coasts but not in the Pacific; *Oerstedia dorsalis* and *Tetrastemma candidum* are circumpolar, being distributed along both the east and west Atlantic and Pacific coasts; *Malacobdella grossa* occurs on both American coasts and in Europe; while the remaining five species, *Carinoma tremaphoros*, *Lineus socialis*, *Micrura leidyi*, *Cerebratulus lacteus*, and *Amphiporus ochraceus* are known only from the Atlantic and Gulf coasts. *Paranemertes biocellata* and *Cerebratulus texanus* have been found only on the northern Gulf coast and may possibly represent endemic species.

Of the seven species herein recorded from southern Florida, only two are known to occur both on the northern Gulf coast and in southern Florida, while *Lineus ater* and *Cerebratulus leucopsis* have been previously reported from Puerto Rico and Curaçao. *Cerebratulus fuscus* occurs also in northern Europe and South Africa, while *Drepanophorus crassus* has an almost world-wide distribution. *Tubulanus floridanus* and *Lineus stigmatus* are at present known only from Biscayne Bay, Fla.

For comparison, it may be noted that 11 of the 53 species found on the North American Atlantic coast are identical with species in European waters, while 12 of the Atlantic coast species occur also on the Pacific coast and 2 of these extend also to Japan. No less than 18 of the species found on the Pacific coast are thought to be identical with well-known European species and others are closely similar.

REFERENCES

COE, W. R. *Biology of the nemerteans of the Atlantic coast of North America.* Trans. Connecticut Acad. Arts and Sci. **35:** 129–328. 1943.

———. *Geographical distribution of the nemerteans of the Pacific coast of North America, with descriptions of two new species.* Journ. Washington Acad. Sci. **24:** 27–32. 1944.

ZOOLOGY.—*A new species of marine nematode*, Thoracostoma magnificum, *with a note on possible "pigment cell" nuclei of the ocelli.* R. W. TIMM, The Catholic University of America. (Communicated by E. G. Reinhard.)

The species of nematode described in this paper was collected from rocks at Point Barrow, Alaska, and sent to Dr. B. G. Chitwood at The Catholic University of America, Department of Biology, for identification. It is here described and figured as a new species of the family Enoplidae, subfamily Leptosomatinae:

Thoracostoma magnificum, n. sp. Fig. 1

Description.—Large worms with an elongate filiform body. Well-developed cephalic helmet (38μ long); slits in the posterior grooves of the helmet not joined. Amphids pocketlike, open—within a ring formed by the helmet; 7.5μ wide in both male and female, one-ninth as wide as the cephalic diameter. Ten cephalic setae in the external circle, four of which are double; six setae in the internal circle. Dorsal tooth very inconspicuous. Dentiform projections in front of the helmet. No excretory pore or subventral excretory gland cell. Ocelli (19μ in diameter) with red-pigmented "retina" and crystalline lens. Cuticle 12μ at the head and tail, 8μ at the midbody. Nerve ring 30 percent of the esophageal length from the anterior in both sexes.

Male.—24 mm long; α, 98.4; β, 9.3; γ, 189. Length of spicules 264μ; length of gubernaculum: corpus 125μ, crus 82.5μ. Total length of testes 33 percent of the body length. One preanal tuboid supplement situated ventrally and nine pairs of accessory papilloid supplements situated subventrally; nine pairs of submedian preanal and two pairs of submedian postanal papillae.

Female.—24 mm long; α, 98.4; β, 9.3; γ, 190. Vulva 64.4 percent from the anterior; both ovaries 31.5 percent of the body length; ovaries reflexed. Two eggs in the uterus, 224μ by 780μ.

Habitat.—Marine.

Locality.—Point Barrow, Alaska.

Specimens.—U.S.N.M. no. 131883 (cotypes).

Remarks.—Filipjev (1916) separated the new

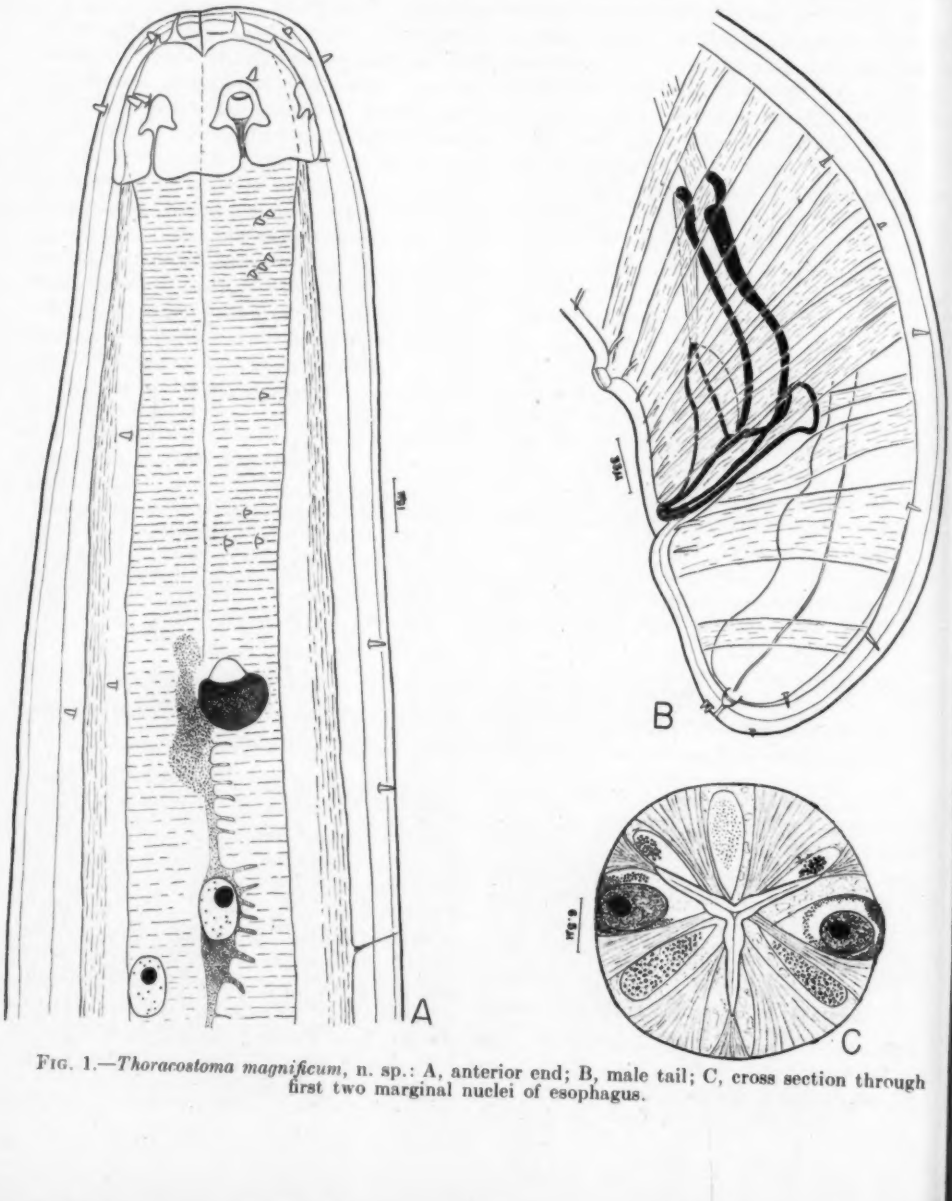


FIG. 1.—*Thoracostoma magnificum*, n. sp.: A, anterior end; B, male tail; C, cross section through first two marginal nuclei of esophagus.

genus *Deontostoma* from *Thoracostoma* on the absence of "large dentiform projections in front." He characterized the genus *Thoracostoma* as having "a hollow ventral tooth." Although *Thoracostoma magnificum* does not have conspicuous teeth as seen in totomount preparations, yet in cross section a definite dorsal tooth, through which the dorsal esophageal gland duct opens, is found to be present. There are also dentiform projections in front. The genus *Deontostoma* has not been generally accepted.

A NOTE ON POSSIBLE "PIGMENT CELL" NUCLEI OF THE OCELLI

Nothing has ever been observed on the innervation of the ocelli of nematodes. Schulz (1931) described a formative cell ("Bildungszelle") directly behind the ocellus of *Parasymplocostoma formosum* [? syn. of *Enchelidium marinum* (Muller, 1783) Ehrenberg, 1836]. He also described a canal ("Augenkanal") opening from the lens to the exterior. These observations have never been confirmed.

In *Thoracostoma magnificum* there are two large nuclei (11μ by 18μ) of the esophagus located a short distance behind the ocelli, which are half-embedded in the lateral walls of the esophagus (Fig. 1, A). These nuclei lie in accessory subventral gland ducts, which are filled with ocellus pigment granules, and lead to the eyes. They are the first two nuclei of the esophagus and represent marginal nuclei (M_1 and M_2); they are surrounded by concentrations of ocellus pigment (Fig. 1, C). In *Leptosomatum elongatum* var. *acephalatum* Chitwood, 1936, and in *Thoracostoma figuratum* (Bastian, 1865) de Man, 1893, we have found these nuclei either in direct contact with the ocelli or a short distance behind them. Since the esophagus is a syncytium, the cytoplasmic boundaries of the cells producing the pigment have not been determined. However, since the regions in which the ocellus pigment extends throughout the esophagus are the same regions in which the marginal nuclei lie, it is suggested that the latter may function as the nuclei controlling pigment production. Possibly the two anteriormost marginal nuclei are specialized for activating the surrounding cytoplasm to produce the ocelli, while the others control the production of the diffuse pigment of the esophagus. However, nothing final can be stated at the present time about definite "pigment cell" nuclei which direct formation of the ocelli.

LITERATURE CITED

FILIPJEV, I. *Les nématodes libres contenus dans les collections du Musée Zoologique de l'Academie Impériale des Sciences de Petrograd*. Ann. Mus. Zool. Acad. Sci. Petrograd **21**: 59–116, pls. 1-2. 1916. (Russian text; French title.)

SCHULZ, E. *Betrachtungen über Augen freilebender Nematoden*. Zool. Anz. **95** (9/10): 241–244. figs. 1–3. 1931.

ZOOLOGY.—*A second record of the polychaetous annelid* Potamethus elongatus (*Treadwell*). E. and C. BERKELEY, Pacific Biological Station, Nanaimo, British Columbia. (Communicated by F. A. Chace, Jr.)

The only specimen hitherto recorded of the polychaetous annelid *Potamethus elongatus* (Treadwell) is in the collection of the U. S. National Museum (no. 5221). It was taken by the steamer *Albatross* in the Hawaiian region in 1902 and briefly described by Treadwell (1906) under the name *Potamilla elongata*. The specimen was later re-examined by Hartman (1942) and attributed to the genus *Potamethus*. It was said to be fragmentary, but the essential details were described.

We have recently been fortunate enough to acquire three specimens of the species, sent to us by Dr. Clifford Carl, of the British Columbia Provincial Museum, Victoria, to whom they had been given by H. E. Wyeth, of the cableship *Restorer*. They were found on sections of the San Francisco to Manila cable brought up for repair. The length of cable involved lies in depths varying from 840 to 1,600 fathoms, about 1,000 miles east of Guam. The specimens are all in good condition and complete, though much contracted, particularly in the peristomial region. One was preserved completely enclosed in its tube, the others partially enclosed. The lengths are, respectively, 50 mm, 51 mm, and 45 mm, the width about 2 mm in each case. The branchial plume, the filaments of which are twisted together in all the specimens, makes up half, or a little more, of the over-all length.

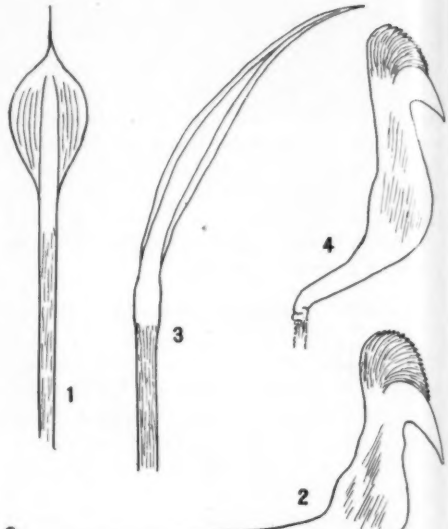
The general appearance agrees with that

of the type species of the genus, *P. spathiferus* Ehlers, the outstanding characters being the high, oblique collar, unbroken dorsally or ventrally, but rising to a high, thickened and grooved, lobe on the dorsal side, the slender body, and the very long branchial filaments (Ehlers, 1887, pl. 54). The dorsal collar lobe varies considerably in appearance in each of the three specimens and is evidently mobile. The long peristomial region, which Ehlers shows for *P. spathiferus* and Hartman says is present in *P. elongatus*, is not apparent in our specimens, but this region is much wrinkled because of contraction and would, no doubt, appear as shown by Ehlers in extension. The branchial bases are slightly, but definitely, involute on the ventral side.

As Hartman points out, *P. elongatus* is definitely differentiated from *P. spathiferus* by the form of the spatulate setae, those of the former species having long mucrons, whereas in the latter they are very little developed. The asymmetry of the blades of these setae in *P. elongatus*, which she stresses, is not invariably present in our specimens; some correspond closely with her figure 15d, others are as symmetrical as shown in our Fig. 1 and by Treadwell (fig. 74), and every intergrade is represented. The form of the thoracic uncinus in our specimens is also not completely in accord with that shown by Hartman (fig. 1c) or by Treadwell (fig. 75). As we find them the stems curve very little or not at all and taper very slightly and gradually, the crests are somewhat higher, and the angle between the beak and neck is rather smaller (fig. 2). These differences may well be within the limits of variation.

The abdominal setae are of two kinds, long capillaries with very narrow blades and others much shorter with wide, flat terminal blades set at a slight angle to the shafts (fig. 3). The abdominal uncini are as shown in Fig. 4. The tubes are quite smooth, the walls very thin and fragile and coated with very fine mud.

Four species have been ascribed to the genus *Potamethus*, all from considerable depths. Of these *P. mucronatus* (Moore), *P. spathiferus* (Ehlers), and *P. elongatus* (Treadwell) seem to be sufficiently clearly differentiated (see Hartman, 1942). There



FIGS. 1–4.—*Potamethus elongatus* (Treadwell): 1, Spatulate thoracic seta; 2, thoracic uncinus; 3, short abdominal seta; 4, abdominal uncinus.

remains *P. scotiae* Pixell. The only notable difference between this species and *P. elongatus* (Treadwell) appears to be in the form of the thoracic uncinus, particularly its very long stem and curious crest (Pixell, 1913, figs. 7a, 7b). Having regard to the variability of the setae in *P. elongatus* we have indicated, we consider it not improbable that the two species are synonymous.

One of the three specimens dealt with in this note is deposited in the U. S. National Museum (no. 22752); the others remain in the authors' collection.

LITERATURE CITED

EHLERS, ERNST. *Florida-Anneliden*. Mem. Mus. Comp. Zool. **15:** 335 pp., 60 pls. 1887.

HARTMAN, OLGA. *The identity of some marine annelid worms in the United States National Museum*. Proc. U. S. Nat. Mus. **92:** 101–140, 8 figs. 1942.

PIXELL, HELEN L. *Polychaeta of the families Serpulidae and Sabellidae collected by the Scottish National Antarctic Expedition*. Trans. Roy. Soc. Edinburgh **49** (pt. 2): 347–358, 1 pl. 1913.

TREADWELL, AARON L.: *Polychaetous annelids of the Hawaiian Islands collected by the steamer* Albatross *in 1902*. Bull. U. S. Fish Comm. **23** (for 1903; pt. 3): 1145–1181, 81 figs. 1906.

MALACOLOGY.—*A new brackish-water gastropod from Texas (Amnicolidae: Littoridina).*[1]

R. T. ABBOTT, U. S. National Museum, and H. S. LADD, U. S. Geological Survey. (Communicated by Julia Gardner.)

During the summer of 1940 the junior author made a study of the brackish-water and marine assemblages of the coastal waters in the vicinity of Rockport and Aransas Pass, Tex. Dredging was done from the bay-head areas near the mouths of streams, where the waters are nearly fresh, through the bays and passes to the Gulf of Mexico, where the waters are of normal marine salinity. The assemblages of mollusks and other benthonic organisms changed radically with the salinity gradient, and it was possible to recognize several distinct facies.[2] The fauna of the bay-head areas was found to be poor in numbers of species but, locally at least, rich in numbers of individuals. One of the most abundant forms is the species of *Littoridina* described in the present paper as the type of a new subgenus, *Texadina*. This new species was found alive only in water of low salinity, but a few worn or broken shells were dredged at intervals from more saline waters all the way to Aransas Pass at a point less than a mile from the open gulf.

Family AMNICOLIDAE

Genus **Littoridina** Eydoux and Souleyet, 1852

Texadina, n. subg.

Shell very small, minutely umbilicate, ovate-conic, with about five whorls, thin but strong. Whorls moderately convex, increasing regularly in size until the last third of the last whorl, which descends more rapidly, becomes constricted and in many specimens detached. Peristome oval to round. Surface smooth, except for fine growth lines. Suture fine, moderately impressed. Periostracum very thin, translucent gray. Operculum chitinous, paucispiral, thin, translucent. Radula and animal amnicolid-like. Type: *T. sphinctostoma* Abbott and Ladd. Recent, Texas.

The subgenus *Texadina* differs from *Littoridina s.s.* in having the peristome constricted and more rounded, and in having the last third of the last whorl more rapidly descending.

Littoridina (Texadina) sphinctostoma, n.sp.
Figs. 1–12

Description.—Shell small (adults 2.0 to 3.3 mm in length), solid, ovate-conic to fusiform, very narrowly umbilicate, 5½ to 6¼ whorls, translucent gray in fresh material to opaque white in dead specimens. Despite its rather fragile appearance, the shell is thick and strong. Apex moderately pointed, with smooth, glossy nuclear whorls not distinguishable from the postnuclear whorls. Sides of whorls moderately well rounded. Last third of the last whorl in most shells descends more rapidly and becomes constricted to form a relatively small, more rounded aperture than is seen in immature specimens. Peristome adnate or in some shells free from the parietal wall, usually thin and strong, but may be thickened either internally or externally. Umbilicus variable in size and shape, frequently deeply rimate or narrowly rounded. Suture sharp, well impressed. Spiral scultpure absent, except for a weak keel on the periphery of the last whorl in young specimens. Axial sculpture of very weak, widely spaced growth lines. Interior of shell highly polished. Periostracum very thin, smooth, translucent grayish to yellowish, lost in dead specimens.

Operculum very thin, chitinous, transparent yellowish, of size and shape of the aperture, and paucispiral. Radula taenioglossate with denticle formula: $\frac{3\text{-}1\text{-}3}{1\text{-}1}$; 2-1-3 or 3-1-3; 15 to 16 for the inner marginal; 9 to 10 for the outer marginal. Animal with moderately short proboscis, moderately long tentacles, with the eyes located at the bases on slight swellings. Color unknown, but black pigment clusters seen above the eye, a vertical band of black-gray on the side of the foot, and a weak dusting of black along a wide band of the mantle edge. Verge unknown.

MEASUREMENTS (mm)

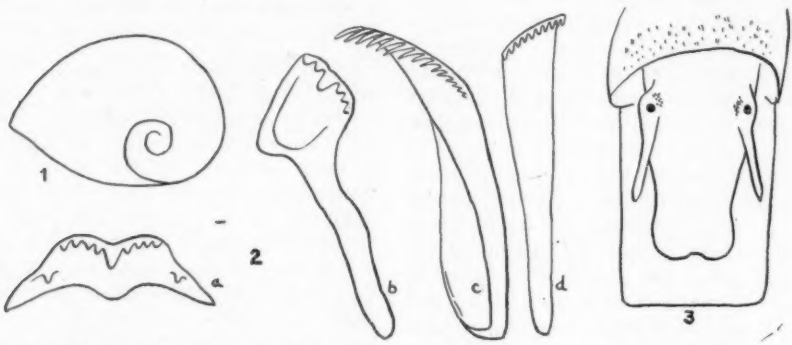
Length	*Width*	*Aperture*	*Whorls*	*U.S.N.M. no.*
3.0	1.4	0.9 x 0.7	6.0	(holotype, 596722)
3.0	1.4	1.0 x 0.8	5.8	(paratype, 596723)
3.0	1.6	0.9 x 0.8	5.7	(paratype, ")
2.7	1.3	0.7 x 0.6	5.5	(paratype, ")
2.4	1.2	0.7 x 0.6	5.0	(paratype, ")

[1] Published by permission of the Secretary of the Smithsonian Institution and the Director, U. S. Geological Survey.

[2] A report on this work has been prepared and will be published by the Institute of Marine Science, University of Texas.

The accompanying graphs represent the shell lengths of adults from random samplings of three dredging stations. Shells in which the last part of the body whorl is constricted and descending are considered adult. Means: Station 2, 2.35 mm; station 3, 2.78 mm; station 6, 2.72 mm. The number of individuals measured at the three stations is respectively 75, 104, and 101.

Types.—The holotype is U.S.N.M. no. 596722 from station 6. Paratypes from station 2 are in the U. S. National Museum (no. 596724), the Museum of Comparative Zoology (Harvard Col-



FIGS. 1–3.—*Littoridina* (*Texadina*) *sphinctostoma*, n.sp.: 1, Operculum; 2, radula, *a*, central, *b*, lateral, *c*, inner marginal, *d*, outer marginal (all greatly magnified); 3, dorsal view of animal (× 20).

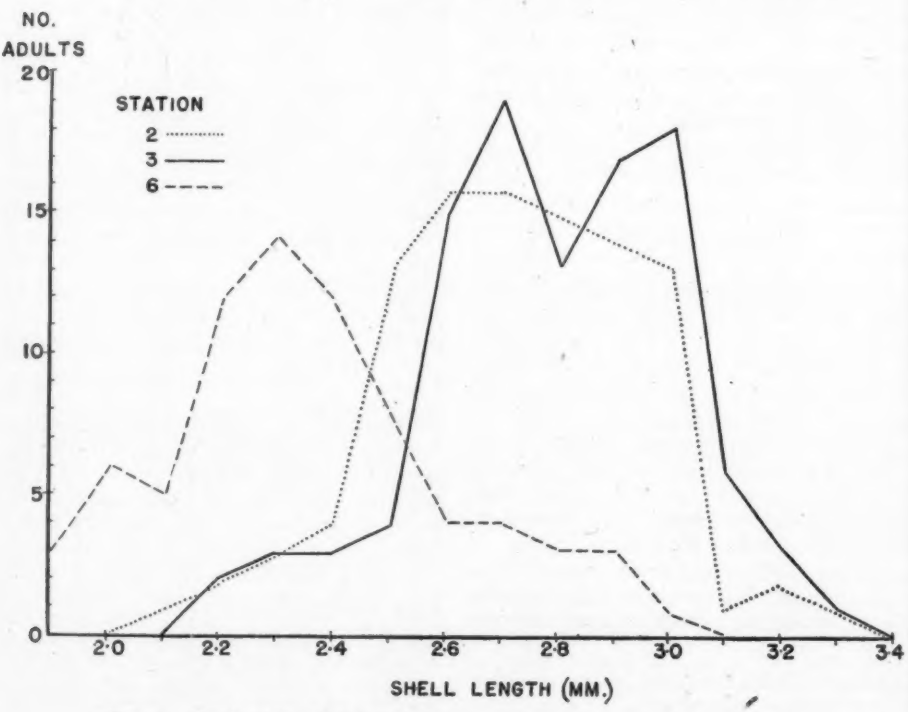
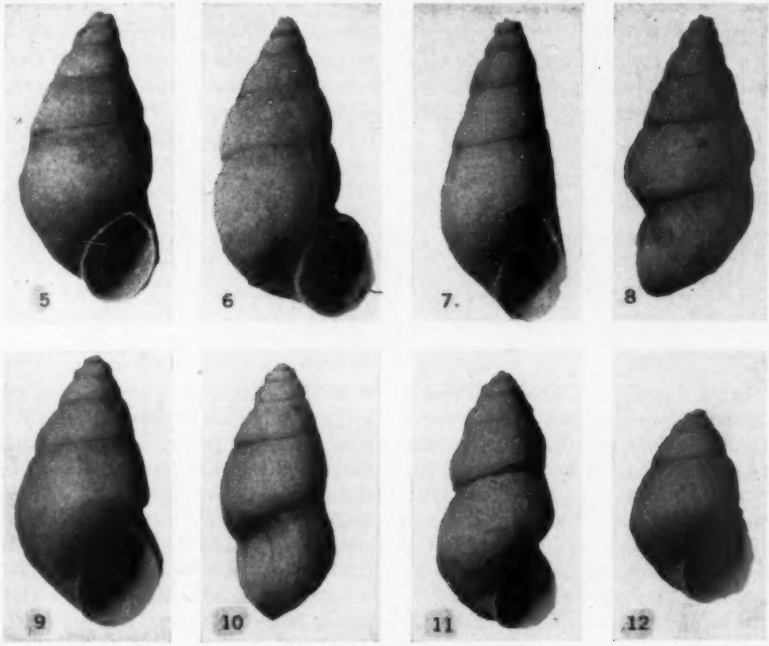


FIG. 4.—Graph of the shell lengths of adults from three population samples.



FIGS. 5–12.—*Littoridina* (*Texadina*) *sphinctostoma*, n.sp.: 5, Holotype; 6–12, paratypes. Fig. 12 is an immature specimen. (All × 15).

lege), the Academy of Natural Sciences of Philadelphia (no. 187519), the Museum of Zoology at the University of Michigan, and the Institute of Marine Science, University of Texas. Paratypes from the other stations are in the U. S. National Museum.

Type locality.—1½ miles north of Webb Point, northwest side of San Antonio Bay, 27 miles northeast of Rockport, Tex. H. S. Ladd, collected July 15, 1940, station 6.

Locality records.—See Table 1 for Texas material. At Grand Isle, La., four specimens were collected by A. G. Humes (U.S.N.M. no. 535757).

Remarks.—The size, texture, and general shape of the shells of *Littoridina sphinctostoma* are not unlike those of *L. tenuipes* Couper from the brackish waters of the Atlantic coast of southeastern United States. Our Gulf of Mexico species, however, is unique in the apertural constriction and the degree to which part of the last whorl descends and becomes detached. The small, oval peristome is rather like that found in *Stenothyra* and *Amphithalamus* (*Floridiscrobs*) *dysbatus* Pilsbry. However, *Littoridina sphictostoma* does not have the dorsal-ventral flattening of the body whorl of those two groups. Young specimens are of a normal littoridinid shape, although a few have a weak ridge at the periphery of the whorls. As shown in Figs. 5 to 12, there is considerable variation in the convexity of the whorls and the degree to which the last whorl descends or becomes detached from the body whorl. In many specimens the unusual change in the last part of the whorl is preceded by injury in some manner to the shell. In some adults, the spire may be slightly concave, giving the shell a fusiform shape. The shells from station 6 are much more variable in shape and are smaller in average size than those from other stations (see graph).

Ecology.—Living examples of *L. sphinctostoma* were recovered only at station 6, a locality at the head of San Antonio Bay about 40 miles from the open gulf at Aransas Pass. The salinity of the water at this locality, according to Galtsoff's map, is between 7 and 8 parts per thousand (Galtsoff, Paul S., *Survey of oyster bottoms in Texas*, Investigational Report No. 6, Bureau of

TABLE 1.—LOCALITY RECORDS (PARATYPES)

Station no. (H.S. Ladd)	Locality (all Texas)	Depth (feet)	Bottom	U.S.N.M. No.	Number of specimens
2	2 miles northeast of Austwell, head of Hynes Bay	2-2.5	Soft mud	596724	150±
3	3½ miles east of Austwell, Hynes Bay	3.5-4	Mud, sand, and shell	596725	200±
4	2 miles west of Seadrift, San Antonio Bay	2	Sand	596729	2
6	1½ miles north of Webb Point, San Antonio Bay	1.5	Muddy sand	596723 (type)	200±
20	South side of mouth of Copano Bay	3.6	Shell and muddy sand	596730	1
28	Southwest corner of San Antonio Bay	4	Muddy sand and shell	596731	2
39	East-central part of Copano Bay	1.5	Muddy sand and shell	596726	15
48	1½ miles east of Mud Island, Aransas Bay	7	Muddy sand and shell	596727	1
61	North side of main Aransas Pass	1-2	Rock jetty	596728	1

Fisheries, fig. 9, p. 15, 1931). Fresh shells were also dredged at three other localities. Two of these are in Hynes Bay, an arm of San Antonio Bay, at points (stations 2 and 3) where the salinity does not exceed 4 parts per thousand. The third locality where abundant shells were collected is in the exposed part of an oyster reef in Copano Bay (station 39), about 20 miles by airline southwest of the type locality. The salinity at this station may be as high as 19 parts per thousand; though abundant, the shells are not as fresh as those dredged in San Antonio and Hynes Bays.

At the type locality in San Antonio Bay the living snails were dredged from a bottom of muddy sand under 1½ feet of water. Associated with the snails are numerous living specimens of *Rangia cuneata* Gray (with attached barnacles), a few of razor clams (*Ensis minor* Dall), and *Mulinia lateralis* Say; also present are numerous Foraminifera: *Rotalia beccarii* (Linnaeus) was the most abundant, with a few tests of *R. beccarii* var. *tepida* Cushman, *Nonion pauciloculum* Cushman, *Elphidium gunteri* var. *galvestonensis* Kornfeld, and *Miliammina fusca* (Brady).[3] The living faunas at stations 2 and 3, where abundant fresh shells of *Littoridina sphinctostoma* were found, are very similar to the living fauna of the type locality with the addition of ostracodes and numerous specimens of the thin-shelled *Tellina texana* Dall. The bay bottom at stations 2 and 3 is of soft mud under 2 to 3½ feet of water.

One or two shells were dredged from a third locality in Hynes Bay, and from localities in Copano Bay, Aransas Bay, and Aransas Pass. None of these was very fresh and most of them were worn or broken; they appear to have been transported appreciable distances from the place where they lived.

[3] Identifications of Foraminifera by Rita Post, of the U. S. Geological Survey.

ORNITHOLOGY.—*Observations on the genera of the swans.* ALEXANDER WETMORE, Smithsonian Institution.

The white species of swans superficially are so alike that there has been difficulty in the identification and application of the older generic names. It is now accepted that the type of the genus *Cygnus* Bechstein, 1803, is *Anas olor* Gmelin, the mute swan, not *Anas cygnus* Linnaeus, the whooper swan, as stated in the fourth edition of the A.O.U. Check-list.[1] In view of this change it is desirable to review the whole question of generic allocation in these interesting birds. The latest comprehensive treatment of the living swans, that of James L. Peters, to which reference has been made, divides the seven living species between two genera, viz., *Chenopsis* for the black swan of Australia and *Cygnus* for the six remaining forms, of which five are found in the Northern Hemisphere, and one, the black-necked swan, ranges in the southern part of South America.

To outline the discussion, the fourth edition of the A. O. U. Check-list[2] recognized

[1] See PETERS, *Check-list of birds of the world* **1:** 143. 1931; and WITHERBY et al., *Handbook of British birds* **3:** 168. 1939.

[2] *Check-list of North American birds*, ed. **4:** 35. 1931.

Sthenelides as the genus for the introduced mute swan, native in the Old World, found now in a feral state in the lower Hudson Valley and on Long Island, ranging in winter south to the coast of New Jersey and east to Massachusetts. The Twentieth Supplement to the Check-list[3] reduced *Sthenelides* to subgeneric status, thus placing all North American swans in one genus. Hildegarde Howard[4] has reopened this allocation by using *Sthenelides* as a genus for the fossil species named *Cygnus paloregonus* by Cope from the Pleistocene deposits of Fossil Lake, Oreg. (It may be observed that *Chenopis atratus* of Australia seems marked generically from other swans mainly by the shorter tail, which is shorter than the middle toe with claw, and the naked lores in the downy young.)

Externally the species of white swans are so similar that the student of study skins has difficulty in separating them. The comparative anatomist, however, working with skeletons, has no trouble whatever in dividing them into two principal groups on characters so evident that they cannot be disregarded. The differences are most apparent in the form of the trachea, sternum, and furculum. Following is a summary of these anatomical characters, with indication of the allocation of the species of the Northern Hemisphere and South America:

a. Trachea passing directly into thorax, not entering sternum; furculum simple; tail cuneate .....genus *Cygnus*

Cygnus Bechstein, Orn. Taschenb., pt. 2, 1803: 404. Type, by monotypy, *Anas olor* Gmelin.

Sthenelus Stejneger, Proc. U. S. Nat. Mus. **5:** 184, 185. Aug. 5, 1882. Type, by monotypy, *Anas melancoripha* Molina. (Not *Sthenelus* Marschall, 1873, emendation for *Sthelenus* Buquet, 1860, for a genus of Coleoptera.)

Sthenelides Stejneger, Auk **1** (3): 235. July 1884. Type, by monotypy, *Anas melancorphia* Molina. New name for *Sthenelus* Stejneger (preoccupied).

Euolor Mathews and Iredale, Austr. Avian Rec. **3** (5): 117. Dec. 28, 1917. Type, by original designation, *Anas olor* Gmelin.

Species included:

Cygnus olor (Gmelin) (skeleton examined).

Cygnus melancoriphus (Molina) (skeleton examined).[5]

aa. Trachea making a loop that enters the sternum; furculum especially modified at symphysis to accommodate this loop; tail rounded.....genus *Olor*

Olor Wagler, Isis, 1832: 1234. Type, by subsequent designation, *Cygnus musicus* Bechstein = *Anas cygnus* Linnaeus (Gray, 1840).

Clangocycnus Oberholser, Emu **8** (pt. 1); 3. July 1, 1908. Type, by monotypy, *Cygnus buccinator* Richardson.

b. Trachea entering anterior end of sternum smoothly, without a dorsal loop. subgenus *Olor*.

Species included:

Olor columbianus (Ord) (skeleton examined).

Olor cygnus (Linnaeus) (skeleton examined).

Olor bewickii Yarrell.[6]

bb. Trachea making a dorsal loop as it enters sternum, protected by a bony case that projects into the anterior end of the body cavity.....subgenus *Clangocycnus*

Species included:

Olor buccinator (Richardson) (skeleton examined).

The shape of the furculum and the looping of the trachea in the sternal keel are developed in the growing young, the loop lengthening and expanding to the end of the sternum as the individual becomes fully adult. This change with age has led to misunderstanding of the characters by some not familiar with it.

The arrangement of the genera above, it may be noted, is identical with that of Stejneger in his *Outlines of a monograph of the Cygninae*, published in 1882.[7]

In checking over the nomenclature concerned for the species in our list a curious

[3] Auk, 1945: 438.

[4] Carnegie Inst. Washington Publ. 551: 160–165. Jan. 25, 1946.

[5] Also the fossil species *Cygnus paloregonus* Cope. See HOWARD, Carnegie Inst. Washington Publ. 551: 160–165, Jan. 25, 1946, where *Cygnus matthewi* (Shufeldt) is placed as a synonym of *paloregonus*.

[6] See YARRELL, *History of British birds* **4:** 320–322. 1884–85.

[7] Proc. U. S. Nat. Mus. **5:** 174–221. 1882.

circumstance that does not seem to have been noted in ornithological literature has come to light relative to the generic name proposed by Stejneger for the black-necked swan. Stejneger in 1882 set up the generic name *Sthenelus* with a proper diagnosis of its characters. Apparently then his attention was drawn to Scudder's *Nomenclator zoologicus*, published in the same year where the following citation is found (p. 303): "*Sthenelus* Buq., col. 1859, M." Following this, two years later Stejneger,[8] in a discussion of Scudder's *Nomenclator*, in which he pointed out some of its shortcomings, wrote: "I find that the name *Sthenelus*, which I applied in 1882 to the black-necked swan from South America was preoccupied. It consequently requires a new one, and I propose in future to call the species *Sthenelides melancorypha*."

Mainly through curiosity I checked the earlier use of *Sthenelus* to find that the reference is to Lucien Buquet in his "Mémoire sur deux genres nouveaux de Coléoptères de la famille des Longicornes (*Oxilus* et *Sthelenus*) suivi de la description appartenant aux genres *Platyarthron*, *Oeme* (*Sclerocerus* Dej.), *Clytus*, *Apriona*, *Cerosterna* et *Acanthoderus*."[9] The generic name in which we are interested is found on p. 621, where it has the same form as in the title, viz., *Sthelenus*, with the footnote "Nom mythologique." The subsequent history of Buquet's name so far as I have followed it is interesting.

Scudder, quoted above, took the name *Sthenelus* from Marschall's *Nomenclator zoologicus* of 1873 as indicated by the initial "M" in his citation. Marschall, on page 245, writes "*Sthenelus*, Buquet," with a reference to the original publication, but with no explanation for the emendation. On a little further research it is found that there is no mythological character from whom Buquet might have taken the term *Sthelenus*, while *Sthenelus* was a well-known name for several ancients of importance, among them a son of Perseus who became King of Mycenae, also a King of the Ligurians whose son Cycnus was reputed to have been changed to a swan, and further one of the warriors who entered the wooden horse at the siege of Troy. It is not apparent whether Marschall recognized what we may consider Buquet's error consciously or unconsciously, but in either case he made the emendation. The matter is correctly set forth by Neave, in his *Nomenclator zoologicus*,[10] where he includes *Sthenelus* of Marschall, 1873, as a new name for *Sthelenus* Buquet, 1860. While it seems curious that neither Stejneger nor Richmond called attention to these matters in their notes on nomenclature, it is fairly certain that the circumstance must have been known to them because of their extensive knowledge and of their careful work in verification of references. In any event, *Sthenelus* of Marschall, 1873, antedated *Sthenelus* of Stejneger, 1882, so that the new name *Sthenelides* Stejneger of 1884 was in order.

[8] Auk, 1884: 235.

[9] Ann. Soc. Ent. France **7**: 619–636. 1859 (1860).

[10] *Nomenclator zoologicus* **4**: 309. 1940.